TURBIDITY MONITORING EQUIPMENT AND METHODOLOGY EVALUATION AT MDOT CONSTRUCTION SITES

STATE STUDY 261

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16. Abstract

State Study 261 is a continuation of State study 225, "Turbidity Monitoring at Select MDOT Construction Sites", which was successful in establishing baseline stream data at several active construction sites. State Study 261 focused on the equipment and methodology of monitoring turbidity upstream and downstream of representative project outfall locations. This equipment evaluation included collecting receiving stream turbidity measurements, evaluating equipment performance in the field, and determining which solutions are more cost-effective, accurate, reliable, and defensible when it comes to monitoring changes in turbidity between the upstream (background) and the downstream locations at representative project discharge locations. Using current MDEQ WQS, sampling points at four monitoring sites were situated upstream and 750 feet downstream from the discharge point. Sampling these locations was determined the most effective way to assess how MDOT construction practices are performing in relationship the current MDEQ WQS.

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EXECUTIVE SUMMARY

The objective of this study was to continue the effort of State Study 225, Turbidity Monitoring At Select MDOT Construction Sites, by evaluating methods and equipment that would be cost effective when establishing a water quality monitoring program on MDOT construction projects. Although the United States Environmental Protection Agency (EPA) proposed numeric turbidity limit for stormwater runoff at construction sites of 280 NTUs was eliminated from 40 CFR Part 450, Effluent Limitations Guidelines and Standards for the Construction and Development Point Source Category, in May 2014; the Mississippi Department of Environmental Quality (MDEQ) Water Quality Standard (WQS) will continue to be enforced. Current MDEQ WQS require that turbidity 750 feet downstream from the point of discharge not exceed the background turbidity levels upstream of the discharge point buy more than 50 NTU.

Three telemetry equipped monitoring devices were selected for the study. YSI, In-Situ and INW were selected for their reputations in the field of water quality monitoring. Each piece of equipment was capable of broadcasting turbidity data from the site using a cellular data connection. The data were then available through web based applications. The equipment used in the study all measured turbidity using the ISO-7027 Standard for measuring turbidity.

Sites were selected for the study using the MDOT approved Sampling and Analysis Plan as a guideline. Streams were evaluated for accessibility, size and the ability to perform monitoring safely. The following four sites were evaluated during the study: Little Tangipahoa River, McComb; Eutacutachee Creek, Pelahatchie; Prairie Branch, Flowood and Trahon Creek, Byram.

Using the MDEQ WQS as a guideline sampling points at each site were situated upstream and 750 feet downstream from the discharge point. A review of the data was conducted and, if sufficient data were collected, the equipment was retrieved from the site and then deployed to another location.

Equipment was evaluated on cost, ease of use and reliability. Deployment and retrieval times along with size and weight of equipment were all considered for evaluating ease of use. Unplanned site visits for maintenance and periods were no data were recorded were logged to evaluate reliability .

Study results indicate that while all three pieces of equipment are known for quality results, the INW product will be the most cost effective and reliable choice for monitoring turbidity at MDOT construction sites. The INW product costs less, is easier to deploy/retrieve and has proven to be more reliable than both the In-Situ and YSI products.

1.0 INTRODUCTION AND PROBLEM STATEMENT

State Study 261 is a continuation of State study 225, "Turbidity Monitoring at Select MDOT Construction Sites", which was successful in establishing baseline stream data at several active construction sites. In State Study 225, data was collected at up-gradient, mixing zone, and down-gradient (750 feet downstream) sample locations to assess potential sediment impacts from adjacent MDOT construction sites. This initial effort was driven by the United States Environmental Protection Agencies (EPA's) proposed rule (40 CFR part 450, effluent limitation guidelines and standards for the construction and development point source category; proposed rule) that would establish the first national effluent (discharge) limit for storm water runoff from construction sites.

After receiving numerous comments on the draft rule, published in November 2008, the EPA evaluated the comments, and issued the final rule in December 2009. This final rule was issued by the EPA which established an average daily numeric turbidity limit of 280 NTU's that would be implemented at sites of 20 acres or more by August 1, 2011 and at sites of 10 acres or more by February 2, 2014. The samples were to be collected at individual point sources on the site. The average daily limitation would not apply on a day of a storm larger than the local 2-year, 24-hour storm event. Following promulgation of the December 2009 final construction and development, several parties filed petitions for review of the final rule, identifying potential deficiencies with the data set that EPA used to support its decision to adopt the numeric turbidity limitations as well as other issues. On December 10, 2012, EPA entered into a settlement agreement with petitioners to resolve the litigation. EPA has since stayed the numeric turbidity limitations and monitoring requirements of the rule in order to provide clarity and allow additional flexibilities. On March 6, 2014 EPA issued a revised rule (New Rule) eliminating the controversial numeric limits for turbidity and changing several non-numeric provisions of the 2009 Rule. However, EPA has reserved sections of the regulation to allow for potential revisions, if EPA decides to propose new numeric standards and monitoring requirements in the future.

However, states with environmental regulatory authority have the ability to impose certain restrictions to the types and quantities of pollutants authorized for discharge into waters of their respective states. The Mississippi Department of Environmental Quality (MDEQ) is one such state that has regulatory authority and has established Water Quality Criteria related to the amount of turbid water that can be discharged from a construction site into a receiving stream. This Study focused on the language within MDEQ's Large Construction General Permit (LCGP - MSR10 expiration date December 31, 2015), Small Construction General Permit (SCGP - MSR15, expiration date March 31, 2018), and Water Quality Criteria as it relates to the amount of turbidity that is allowed downstream from outfalls on MDOT's linear transportation projects.

MDOT constructs linear transportation projects under several environmental regulatory guidelines such as those found within Clean Water Act (CWA) Sections 401, 402, and 404. The MDEQ has regulatory authority over CWA Section's 401 and 402 while the United States Army Corps of Engineers provides regulatory authority over the CWA Section 404 program.

The MDEQ, through the CWA Section 401, has established water quality criteria or standards (WQS) and has established minimum conditions of turbidity applicable to all waters. Specifically, *"…waters shall be free from materials attributable to municipal, industrial, agricultural, or other discharges producing **color**, odor, taste, total suspended or dissolved solids, **sediment**, **turbidity**, or other conditions in such a degree as to create a nuisance, render the waters injurious to public health, recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, and aesthetic quality, or impair the waters for any designated use.* The minimum conditions set forth in the Water Quality Criteria further state that, *"... the turbidity outside the limits of a 750-foot mixing zone shall not exceed the background turbidity at the time of discharge by more than 50 Nephelometric Turbidity Units (NTU's)."*

The MDEQ, through the CWA Section 402, also establishes and issues Storm Water General Permits including the LCGP that most MDOT linear transportation projects operate under. This storm water general permit authorizes a category of discharge within a geographical area and is not specifically tailored for an individual facility or project but more for those projects impacting > 5 acres or more. There is also a SCGP which is issued for those projects impacting >1 acre. The LCGP and SCGP do not have a turbidity limit; however, they do incorporate language to support language found within the CWA Section 401, Water Quality Criteria, in that their conditions state that receiving streams shall be free of *"…Suspended solids, turbidity and color at levels inconsistent with the receiving waters"*. The LCGP and SCGP do not have a requirement for monitoring turbidity but do provide guidance on minimum requirements for those wanting to voluntarily collect, analyze, and document this parameter as a guide toward improving the efficiency of sediment and erosion controls on their projects.

State Study 225 was successful in establishing baseline stream data utilizing upgradient, mixing zone, and downgradient (750 feet downstream) sample locations to determine impacts from adjacent MDOT construction sites, but the study revealed reliability issues with the monitoring equipment selected to collect the data. State Study 261 focused on the equipment and methodology of monitoring turbidity upstream and downstream of representative project outfall locations. This equipment evaluation included collecting receiving stream turbidity measurements, evaluating equipment performance in the field, and determining which solutions are more cost-effective, accurate, reliable, and defensible when it comes to monitoring changes in turbidity between the upstream (background) and the downstream locations at representative project discharge locations. Furthermore, this effort will demonstrate MDOT's continuing efforts to be proactive with respect to environmental issues and regulations.

2.0 SAMPLING AND ANALYSIS PLAN

A Sampling and Analysis Plan (SAP) was prepared and discussed with MDOT in December 2013. Field work was conducted using the SAP as a guideline. The SAP included discussions regarding project objectives, sample protocol, sampling equipment, health and safety, and data analysis and reporting. A summary of the SAP as well as deviations from the SAP are discussed in the following sections.

2.1 Site Selection

Sites were chosen based on the following criteria:

-Accessibility
-Stream size/ flow rate
-Construction phase
-Safety considerations
-MDOT Approval

Accessibility—Streams were selected based on ease of accessiblity with equipment and materials needed to deploy monitoring equipment.

Stream size/ flow rate— Intermittent and ephemeral streams were excluded from selection due to the probability of a low/no flow condition. Additionally, large streams with deep channels and high flow volumes will be excluded due to safety issues related to working in such bodies of water.

Construction Phase— In order to obtain sufficient data, the project construction phase was considered during site selection. Construction sites nearing completion would not provide enough time to collect data. Additionally, data from these sites would not reflect construction conditions, due to the vegetative cover associated with projects nearing completion.

Safety considerations— Safety was considered at all times in the field and during site selection. Channels with extremely steep banks and fast currents were not be considered due to the risks associated with deploying equipment and in these conditions. Traffic conditions were also considered during site selection.

MDOT Approval— Final site selection was approved by MDOT.

The following locations were selected for this study:

Little Tangipahoa River
Eutahutachee Creek
Praire Branch
Trahon Creek

Figure 1 shows the location of these sites, and Appendices A through D include location of sampling points, aerial photographs, data trend charts, and photos for each location.

2.2 Sampling Locations

Using current MDEQ WQS, sampling points at each site were situated upstream and 750 feet downstream from the discharge point. Sampling these locations was determined the most effective way to assess how MDOT construction practices are performing in relationship the current MDEQ WQS.

2.3 Sampling Equipment

three telemetry equipped water quality monitoring devices were selected for comparison in the study. YSI, In-Situ and INW were selected for the study because each manufacturer is considered a leader in the field of water quality monitoring. Each monitoring device was installed with a modem that was capable of broadcasting turbidity readings to web based applications where data could be monitored at time intervals requested by the user.

Additionally, precipitation monitoring was conducted at each site. A combination of tipping bucket style rain gauges (RainWise) and RainWave Precipitation Monitoring was used at various times during the study. RainWave Precipitation Monitoring is a service that uses a network of weather stations and Doppler Radar to extrapolate rainfall data at a given latitude and longitude. The fee for the service is $100 per site setup fee and $25/month for monitoring.

Specification sheets for all equipment used can be found in **Appendix E**

2.3.1 Equipment Deployment

During deployment stage a site reconnaissance was conducted to determine the easiest route in to the sampling location. Then, monitoring equipment was packed in to the location. When access was available ATVs were used to reduce the number of trips from truck to site. Once all of the equipment was at the sampling location, a post hole digger was used to install the console. If it was determined that the soil was not stable enough for the console to remain upright during a high water event, the console was installed using concrete mix. After the console was installed and supported with braces or otherwise stabilized, equipment installation began. Equipment was installed one manufacturer at a time to accurately record installation time for each. After equipment was installed on the console, a metal t-post was installed in the stream channel in order to mount the sondes. Cables were run from the equipment boxes through 2-inch PVC pipe, to the sondes.

2.4 Data Monitoring and Retrieval

Data was monitored using web based applications provided by manufacturers of the three different pieces of equipment.

After it was determined that sufficient data were collected the site was visited to retrieve equipment and data were manually retrieved from the equipment using a laptop computer.

Data from the RainWise rain gauge were extracted using RL-Loader 2.2. Data could be extracted by daily rainfall amount, five-minute interval or by rainfall event.

2.5 Deviations from the SAP

The MDOT approved SAP stated that calibration sampling was to be conducted at each study site. During the calibration sampling period each pair of sondes would be installed at the downstream sampling location. After collecting data from two rain events, the upstream sondes would be moved to their long term sampling location. This procedure was in place to ensure that equipment was working properly and to calculate any margin of error that may have been determined during the calibration sampling period. However, once field work began it was determined that this procedure was not necessary. The paired equipment , no matter how close in proximity to each other, would not be taking the exact same sample. Therefore, any difference in readings could be true. If this was calculated as an error, turbidity measurements would, possibly, be imprecise. Additionally, any issues with equipment functionality could be addressed regardless of location.

Along with calibration sampling, grab sampling was determined to be unnecessary. The SAP stated that during each site visit grab samples would be collected and compared to data collected from the remote monitoring equipment. This procedure required two people to be in position at the study site during rain events to collect samples throughout the work day. Logistically, this task was impractical because of driving tomes to the study sites and personnel requirements. However, a simulated cost comparison between remote monitoring and manual sampling was created for the study.

3.0 INDIVIDUAL SITE DESCRIPTIONS

This section provides descriptions of the site and the stage of construction during a sampling event. Appendices A-D include site location maps, aerial photographs and turbidity data charts for each location. The site photos are representative of conditions and BMPs present during the sampling event. Data charts represent turbidity behavior during rain events.

3.1 Little Tangipahoa River— I-55, McComb, Mississippi

The initial study site was located in McComb, Mississippi. Construction activities on the project included the widening of five bridges on Interstate 55 between the MS/LA state line and Lincoln/Pike County line. Turbidity monitoring at the site was conducted between March 6, 2014 and April 3, 2014. The area of interest for this study was the bridge widening over the Little Tangipahoa River, approximately 1 mile north of the intersection of I-55 and US-98. Soil disturbing activities included the driving of piles in the Little Tangipahoa river as well as earth moving activities associated with bridge construction. The approximate disturbed area for the bridge widening project was 1.8 acres.

Monitoring Equipment was deployed 250 feet upstream of the construction site and 750 feet downstream from the site.

A map of the location can be seen in **Figure A-1**. An aerial photograph of the site can be seen in **Figure A-2**. Photographs of the site and BMPs in place can be seen in **Appendix A**, **Photos A-1** through **A-14.**

3.2 Eutacutachee Creek—US 80, Pelahatchie, Mississippi

The second data collection site in the study was located in Pelahatchie, Mississippi. Improvements to US 80 at the site included the construction of a new bridge. Turbidity monitoring at the site was conducted between April 24, 2014 and May 6, 2014. The area of interest for this study is the bridge replacement at Eutahutachee Creek. A detour bridge was constructed parallel to the existing bridge. When construction of the detour bridge was complete, traffic was diverted across the detour bridge while the old bridge was replaced. The approximate disturbed area for the bridge replacement was 1.8 acres.

Erosion and sedimentation control BMPs on the site included super silt fence along the channel bank and rip rap check dams in ditches leading to the creek

Monitoring equipment was deployed 250 feet upstream of the construction site and 750 feet downstream from the site

A map of the location can be seen in **Figure B-1**. An aerial photograph of the site can be seen in **Figure B-2**. Photographs of the site and BMPs in place can be seen in **Photos B-1** through **B-9.**

3.3 Prairie Branch-SR 468 Flowood, Mississippi

The third data collection site in the study was located in Flowood, Mississippi where SR 468 crosses Prairie Branch. Improvements to SR 468 at the site included the widening of the existing two-lane highway into five lanes and replacement of the bridge over Prairie Branch. Turbidity monitoring at the site was conducted between May 8, 2014 and June 6, 2014. The area of interest for this study was the bridge replacement at Prairie Branch. During the monitoring period, construction of a second bridge was ongoing. Soil disturbing activities at the site included pile driving and slope modifications. The approximate disturbed area for the bridge replacement was 3.3 acres.

Erosion and sedimentation control BMPs on the site included the following: silt fence around the perimeter of the disturbed areas, slopes lined with rip rap or vegetation, silt fence along the channel slope and a turbidity curtain in the stream.

Monitoring equipment was deployed 250 feet upstream of the construction site, in the mixing zone and 750 feet downstream from the site.

A map of the location can be seen in **Figure C-1**. An aerial photograph of the site can be seen in **Figure C-2**. Photographs of the site and BMPs in place can be seen in **Appendix C**, **Photos C-1** through **C-4**.

3.4 Trahon Creek- I 55 Byram, Mississippi

The fourth data collection site in the study was located in Byram, Mississippi where I-55 crossess Trahon Creek . Improvements to SR 468 at the site included the construction of a new bridge. Turbidity monitoring at the site was conducted between June 11, 2014 and June 27, 2014. The area of interest for this study was the bridge replacement at Terrapin Skin Creek. A detour bridge was constructed parallel to the existing bridge. When construction of the new bridge was complete, traffic was diverted across the new bridge while the old bridge was replaced. The approximate disturbed area for the bridge replacement was 6 acres.

Erosion and sedimentation control BMPs on the site included the following: silt fence around the perimeter of the disturbed areas, storm water outlets protected with silt fence,
rip-rap, and a rip-rap lined sediment basin near the stream channel.

Monitoring Equipment was deployed 250 feet upstream of the construction site, in the mixing zone and 750 feet downstream from the site.

A map of the location can be seen in **Figure D-1**. An aerial photograph of the site can be seen in **Figure D-2**. Photographs of the site and BMPs in place can be seen in **Appendix D**, **Photos D-1** through **D-3.**

4.0 EQUIPMENT DESCRIPTIONS

For the study, equipment from YSI, In-Situ and INW were chosen. The YSI and INW products were rented from Pine Environmental and EON Products, respectively. The In-Situ Troll 9500s used during the study are owned by Thompson Engineering. However, telemetry equipment for the In-Situ product was rented directly from In-Situ.

The Mississippi Department of Environmental Quality Large Construction General Permit lists four criteria that turbidity meters must meet to be used for monitoring. The criteria are listed in ACT9, Condition T-5 as follows:

- Accuracy within ± 5% of measurement
- Minimum upper range of 1,00 NTU
- User calibrated, and
- Operating temperature range of at least 32-122 °F.

Table 1

	YSI	In-Situ	INW
Operating Temperature (°F)	23-122	23-122	32-104
Accuracy	± 2%	±5%	± 2%
Measuring Method	ISO-7027	ISO-7027	ISO-7027
Range (NTU)	0-1,000	0-2,000	0-1,000
User Calibrated	YES	YES	YES

Sampling intervals of 5 minutes were used at all locations during the project. The telemetry system was programmed to broadcast data to web based data server at 1 hour intervals. The costs of associated cellular accounts was included in the rental agreement with each supplier.

Each of the three systems used are capable of being powered using solar panels. However, due to heavy cover at most of the sites they were deployed using battery power only.

4.1 YSI

The YSI 600 XLM V2 Water Quality Sonde (V2) and Nertronix Thiamis ICU 820 (modem) were paired together to evaluate YSI products. The V2 was equipped with a 6136 optical turbidity sensor. This particular sensor has measuring threshold range of from NTU to 1,000 NTU. The modem broadcasts data using a cellular connection. Sampling parameters and intervals were programmed for the study using the 650 MDS Handheld unit. This set up was powered by an 12 volt deep cycle marine battery.

The modem and battery were housed in a large weather resistant box. A weather resistant junction box allowed for cabling from the sonde to be connected to the battery and modem.

Data were available at https://ienvironet.com/dashboard. The web based data hosting site allows the user to monitor turbidity from any web enabled device. At the end of the rental period the information collected is stored in CSV format, allowing the user to access data after the rental period.

The total shipped weight for all of the equipment from YSI was 251 lbs. It should be noted that this weight includes the batteries and tripods supplied by Pine Environmental.

4.2 In-Situ

The Troll 9500 (TROLL) was paired with the TROLL Link 101 telemetry system to evaluate In-Situ products. The TROLL is a multi-parameter water quality sonde with a turbidity measuring threshold of 2,000 NTU. The TROLL Link broadcasts data using a cellular connection. Sampling parameters and intervals were programmed for the study using the provided Win-Situ 4 software.

This system was powered by three 12 volt, 8 Ah batteries housed in two weather resistant boxes. The boxes, which were supplied by In-Situ, contained batteries, modem and solar charge controller.

Data were available at http://www.isi-data.com. The web based data hosting site allows the user to monitor turbidity from any web enabled device. Collected data can be viewed in graph mode or list mode from the website and can be exported in CSV format. Additionally, reporting interval can be manipulated through the website.

The total shipped weight for all of the equipment from In-Situ was 85 lbs.

4.3 INW

The INW Turbo Turbidity Sensor (Turbo) was paired with the Wave Data VZCOM telemetry system to evaluate INW products. The Turbo is a turbidity only water quality sonde with a turbidity measuring threshold of 1,000 NTU. The VZCOM broadcasts data using a cellular connection. Sampling parameters and intervals were programmed using the data hosting site at http://www.myinwdata.com. The VZCOM is a self-contained weather resistant modem and data logger that eliminates the need for additional mounting boxes; therefore, substantially reducing weight. This system was powered by one 12 volt deep cycle marine battery. INW also supplied a tipping bucket style rain gauge that could be monitored through the online application.

As seen in Table 1, the Turbo does not meet the MDEQ maximum temperature range requirement for turbidity monitoring. A maximum temperature of 122°F may be suitable for industrial monitoring, however stream temperatures are not likely to reach this high at a construction site.

Data were available at http://www.myinwdata.com/#. The web based data hosting site allows the user to monitor turbidity from any web enabled device. Collected data can be viewed in graph mode or list mode from the website and can be exported in CSV format. Additionally, reporting interval and sampling interval can be manipulated through the website.

The total shipped weight for all of the equipment from INW was 23 lbs.

5.0 RESULTS

As stated in the approved Sampling and Analysis Plan, the goal of this research project was to evaluate different types of turbidity monitoring equipment and methodologies at various receiving streams at MDOT construction sites while continuing to build on State Study 225 by collecting and recording changes in turbidity between upstream and downstream locations of select point source discharge locations. This evaluation included assessing equipment reliability and identifying technologies effective at producing reliable changes in turbidity levels under varying stream conditions above and below point source discharges.

At each monitoring site, equipment from each manufacturer was deployed by Thompson employees. During the deployment, one set of equipment was installed at a time to accurately record differences in set-up times. . All of the modems and batteries were mounted to the console and cables were run through PVC pipe to the sondes in the stream. Various methods were tested for mounting sondes in the water.

5.1 Equipment Evaluation

The equipment used in the study were evaluated on the following criteria: cost, reliability, and ease of use. Cost evaluation includes the initial cost to purchase equipment and materials for installation, installation labor and periodic site visits for maintenance.

5.1.1 Cost

In order to remain with in the equipment budget for the study, the majority of equipment was rented. The total cost of YSI equipment from Pine Environmental was $5,054. Due to the high rental cost, YSI equipment was used only at the Little Tangipahoa River study site for a period of one month. The total cost for INW rental was $10,340.68 for a rental period of four months. The rental cost for In-Situ equipment was $8,249.02 for a rental period of four months. In-Situ equipment consisted of only telemetry equipment , cabling and cellular device expenses.

Looking at rental costs alone, the INW product is the most logical choice for long term monitoring. Purchase price is similar to rental price, in that the INW product is the least expensive. While the INW Turbo measures only turbidity, both the YSI and In-Situ products are set up to measure multiple parameters and this is reflected in the cost. During equipment selection, no other turbidity only sonde was available.

Although grab sampling was not conducted at any of the study sites, a cost simulation comparing manual sampling to remote monitoring was created. Table 3 summarizes the cost of manual sampling vs. remote monitoring. The 2-yr cost for manual sampling was derived from the average number of rain days in Jackson, Mississippi. According to Current result (www.curentresults.com), Jackson averages 109 rain days per year. Assuming that two people will be sampling and using the LCGP sampling guideline of three samples per 8 hour workday should be taken the total man hours per year are 1744.
The hourly rate of $10/hr assumes that a general laborer, not a person in a skilled trade position, will be performing sampling to minimize costs. The cost of $600 for the turbidity meter was averaged from multiple retailers online pricing.

The cost of remote monitoring uses the same hourly rate assuming that general laborers will be used for installation and maintenance of equipment . The cost of INW equipment was used because it is the least expensive of the equipment used in the study. The cost of $24,000 includes equipment and materials that may be necessary for installation/maintenance. Man hours were calculated based on at least one site visit per month by two people. Extra hours are included to cover any unexpected visits for unforeseen maintenance issues.

Table 2

	Grab Samples	Monitoring Equipment (INW)
Initial Cost *	$600	$24,000
Man Hours/Yr **	1744	240
Hourly Rate	$10	$10
Duration (Years)	2	2
Total Cost	$35,480	$28,800

* Approximate cost of monitoring equipment. $600 for Hanna Instruments Portable Turbidity Meter, $24,000 for 4 complete Turbo setups from INW

** 1744= 2 Employees x 8 hrs. x 109 days, 150 = 2 Employees x 8 hrs. x 15 Days

5.1.2 Ease of Use

The INW product seemed to be the most practical method for use at MDOT construction sites. The complete set up could be easily deployed by two people in the least amount of time . The VZCOM and Turbo set up weighs slightly over 10 pounds and can be carried in a large back pack. During this study, the VZCOM was installed on the console with other equipment but could easily be installed on a tree at the monitoring location. The average set up time for INW equipment was considerably less than the YSI or In-Situ products. Additionally, The ability to set sampling intervals and uplink interval from remote computer adds to the ease of deployment of the INW product.

The YSI equipment was the least user friendly. The large container required to house the modem is heavy and takes up more room that any of the other equipment tested in the study. Additionally, sampling parameters must be configured using the YSI handheld programmer.

While the In-Situ product was considerably more manageable with relationship to the size of the boxes housing the equipment, it still requires the use of some type of post for installation. In-Situ also requires sampling parameters to be programmed in the field using a laptop computer.

5.1.3 Reliability

Operating issues occurred with all of the selected equipment. Issues ranged from simple fixes such as power loss to equipment failures which required equipment to be returned to the manufacturer. The following paragraphs describe recorded issues during the study.

The YSI setup was never operational as a pair (upstream/downstream). After the initial site visit, two additional site visits were required to attempt to resolve the issue with the downstream sampling location. After replacing data cables in the telemetry system, it was determined that the issue was with the sonde itself and the equipment was re turned to Pine Environmental.

The In-Situ setup performed well through the first half of the study. One additional site visit was require during the Little Tangipahoa deployment to program the sampling parameters on the sonde. Data were collected from pair at the Little Tangipahoa and Eutahutachee Creek study sites. During deployment at the Prairie Branch study site it data collection was sporadic at both sampling locations and no data was collected during the second rain event at this location. The decision was made to replace the downstream sonde before the final deployment at Trahon Creek. No data were collected from the Trolls during deployment Trahon Creek.

The INW Turbo reliably collected turbidity throughout the majority of the study. During the Prairie Branch deployment it was noted that the equipment was giving unusual readings. During an additional site visit it was discovered that water levels in the creek had dropped significantly and all of the equipment was out of the water.

5.2 Turbidity Data Collection

The following sections are a summary of turbidity behavior during rain events. Data were collected and compiled into charts using Microsoft Excel. The charts are available in Appendices A-D.

5.2.1 Little Tangipahoa River

Data from three rain events was captured at the Little Tangipahoa monitoring site. The first began on March 15th at 20:10 and lasted until march 16th at 05:18. A total of 1.29 inches of rain was reported during this event. During the event, the turbidity reading indicated that the project site remained within the 50 NTU MDEQ WQS until 04:00 on the 16th. The site remained out of compliance until 04:55, a duration of 55 minutes. The second rain event started at 04:51 on the 23rd of March and lasted until 06:34. A total of 0.44 inches of rain was reported during this event. Turbidity readings indicated that the site remained within the MDEQ WQS for the duration of the rain event.

However at 08:25 the site was noncompliant until 09:40. The third rain event began on the 27th of March at 21:05 and lasted until the 28th of March at 23:29. A total of 0.79 inches of rain was reported during this event. The site remained in compliance throughout this event.

5.2.2 Eutacutachee Creek

Data from two rain events were collected at the Eutacutachee Creek monitoring site. The first began on April 27th at 05:58 and lasted until 13:02. A total of 1 inch of rain was reported during this event. Data from the Turbo indicated a period of noncompliance beginning at 08:30 on April 27th and lasting until 10:35. Another period of noncompliance was recorded at 1355 and lasted approximately 4 hours. The Troll indicated that four periods of noncompliance lasting ten minutes or longer. Turbidity readings indicate that the site was not consistently in compliance until 10:00 on the 28th.

The second rain event began on the 28th of April at 13:34 and lasted until the 29th at 09:54. Total rainfall for this event was recorded at 0.38 inches. The Turbo indicated that the site was had a period of noncompliance beginning at 19:15 on the 28th lasting until 21:40. After 21:40 sporadic periods of noncompliance were recorded with the longest lasting from 22:40 until 23:25.

5.2.3 Prairie Branch

Two rain events were recorded at the Prairie Branch monitoring location. The first rain event began on May 9th at 02:35 and lasted until may 10th at 23:34. Total rainfall for this event was recorded at 0.63 inches. The downstream Turbo is believed to have malfunctioned during this rain event. Before the rain event, a reading of 582.573 NTU was recorded. Throughout the rain event, the readings from the downstream turbo were sporadic and stayed above 570 NTU regardless of the upstream reading. The upstream Turbo indicated that turbidity began increasing around 10:00 until it reached a high of 926.4 NTU at 15:40 on May the 9th.

The second recorded rain event occurred on the14th of May at 08:30 and lasted until19:00. A total of 0.15 inches of rain was recorded during this event. No noncompliance periods were recorded by the Turbo during this event. No data were collected from the Trolls.

5.2.4 Trahon Creek

Three rain events were recorded at the Trahon Creek monitoring location. The first event began on the 13th of June at 03:14 and lasted until 08:18. A total of 0.29 inches of rain was recorded during this event. Data from the Turbo indicate that the site was out of compliance from 08:50- 17:55. The average difference in between the upstream and downstream monitoring locations was 270 NTU. The second recorded rain event occurred on June 24. This event lasted from 11:14 until 13:23 with a total of 0.35 inches of rainfall. There were no periods of noncompliance during this event. The third even occurred on June 25th at 17:35 lasting until 19:42. Data indicate that aperiod of noncompliance occurred between 18:20 and 22:25. Several readings above the 1000 NTU measuring limit were recorded. The average difference between upstream and downstream monitoring locations during the this period was 10 NTU.

6.0 CONCLUSIONS AND RECOMMENDATIONS

During the study it was determined that each of the three monitoring devices have shortcomings. Based on cost and ease of use it was determined that the INW product is the best solution for monitoring turbidity at MDOT construction sites. The Turbo and VZCOM can easily be deployed by two people in a relatively short amount of time. The ability to manipulate both sampling interval and uplink schedules remotely only adds to the ease of use. Additionally, a supplemental data hosting program. Data Sight, is available for the INW product. Data Sight is a data management program that allows the monitoring of an unlimited number of sites on the web based application.

The goal of State Study 261 was to continue the efforts of State Study 225 by collecting additional turbidity data and to evaluate methods and equipment for turbidity monitoring at MDOT construction sites. Data collected during the study reflect the conclusions of State 225. If properly installed and maintained, MDOT's current BMPs are capable of meeting the MDEQ Water Quality Standards. Additionally, it was determined that remote monitoring can be a much more cost effective method for monitoring turbidity at MDOT construction sites.

REFERENCES

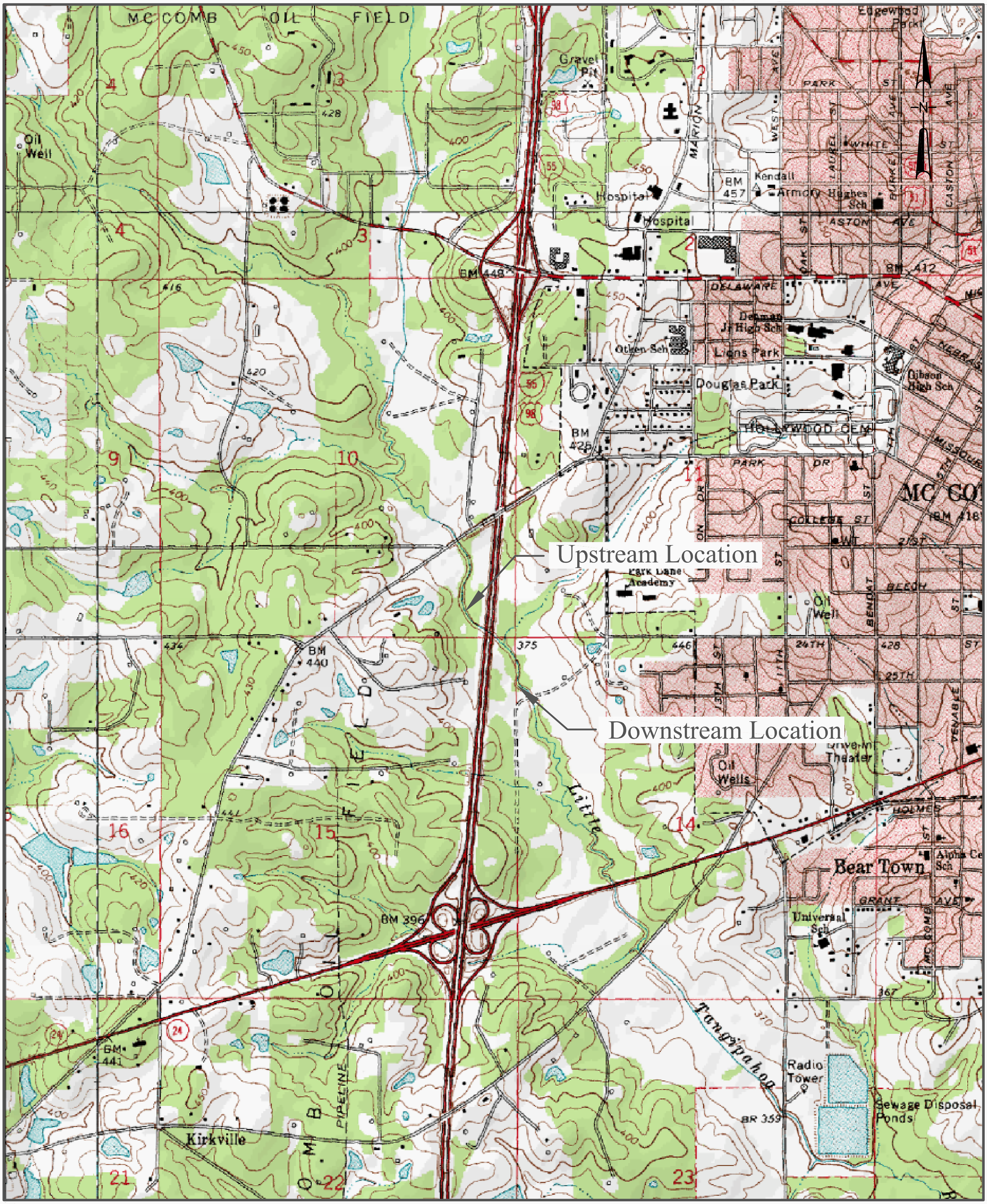
1. State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters. Adopted by the Mississippi Commission on Environmental Quality August 23, 2007.

APPENDIX A

Figures, Charts, and Photographs

Little Tangipahoa River— I-55, McComb, Mississippi

FIGURES



MDOT Turbidity Equipment Evaluation
Little Tangipahoa River
McComb , Mississippi

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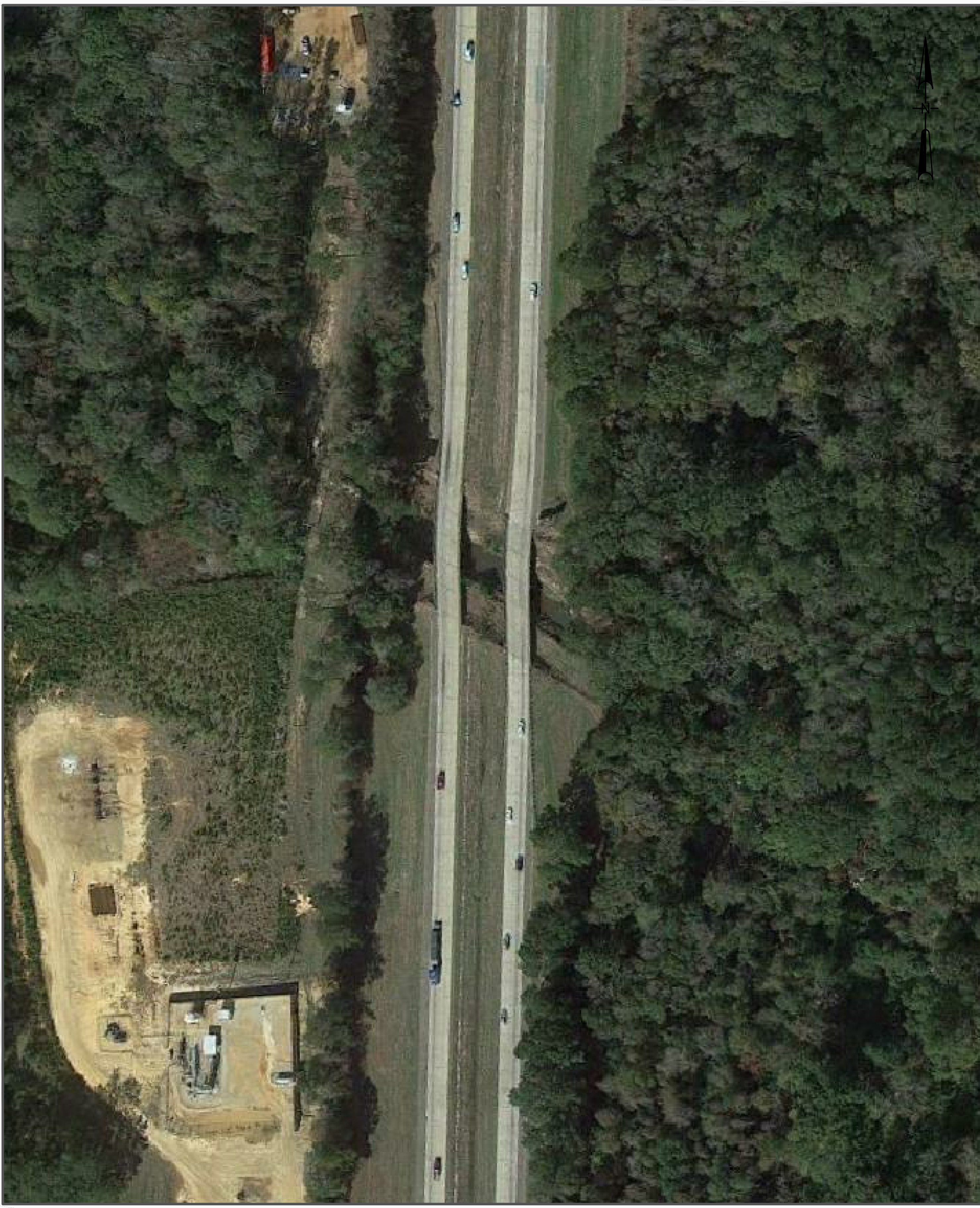
Figure A-1
Topo Map

PROJECT NO: 13–1106–0026

DATE: Sep 2014



MDOT Turbidity Equipment Evaluation
Little Tangipahoa River
McComb , Mississippi

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Figure A-2
Aerial Photo

PROJECT NO:	DATE:
13-1106-0026	Sep 2014

CHARTS

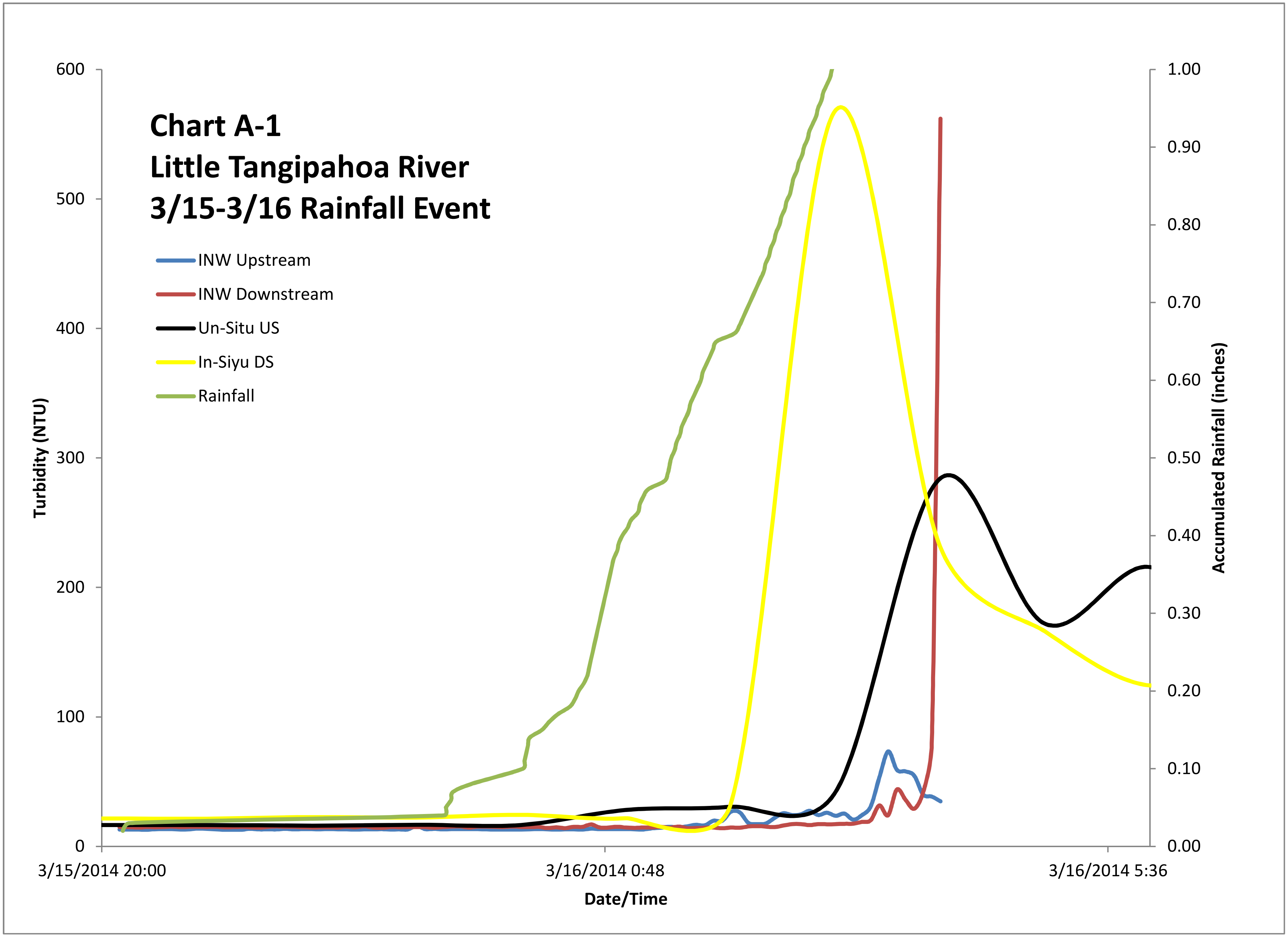

Chart A-1
Little Tangipahoa River
3/15-3/16 Rainfall Event
INW Upstream
INW Downstream
Un-Situ US
In-Siyu DS
Rainfall
Turbidity (NTU)
Accumulated Rainfall (inches)
Date/Time
600
500
400
300
200
100
0
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3/15/2014 20:00
3/16/2014 0:48
3/16/2014 5:36

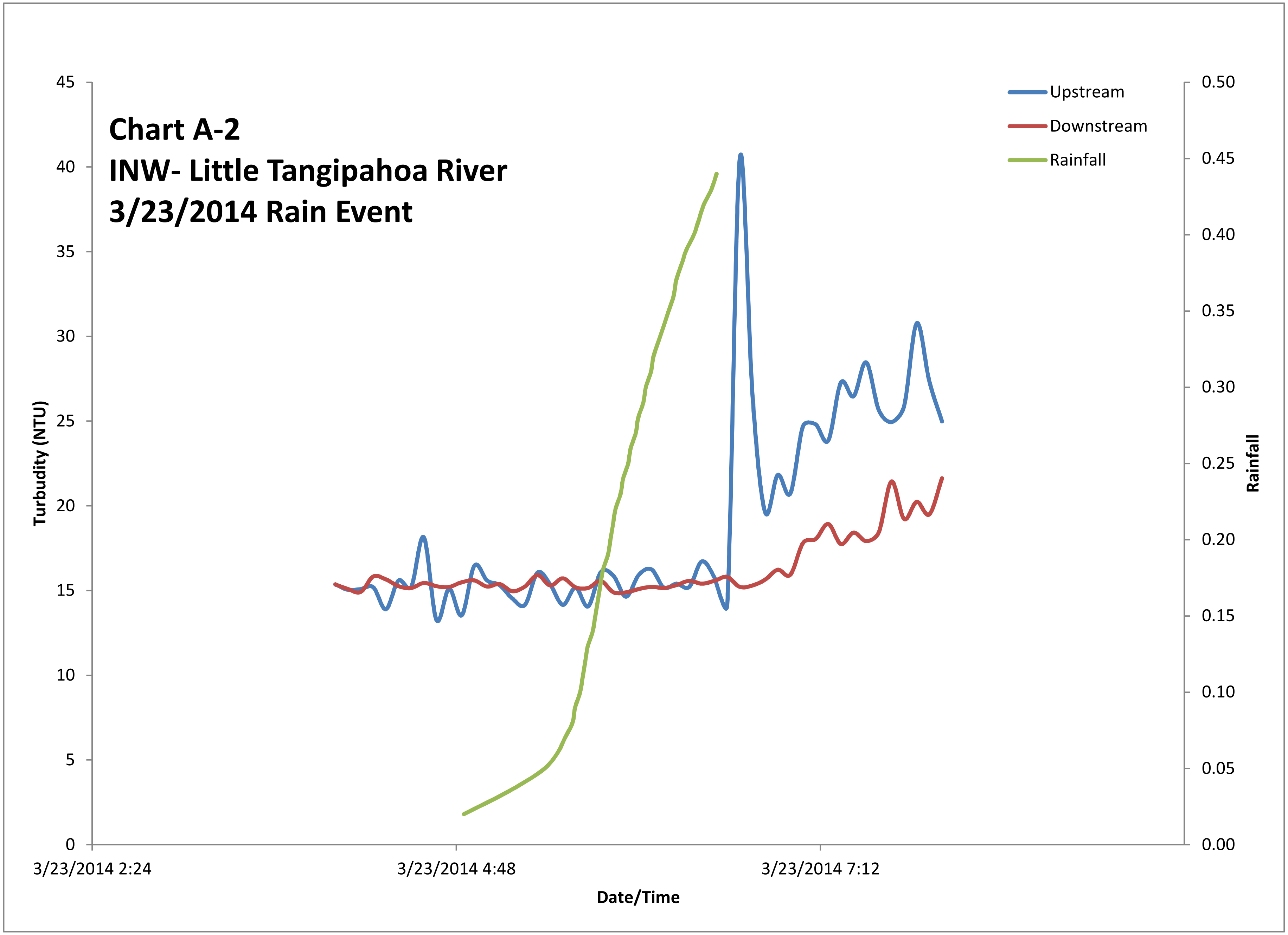

Chart A-2
INW- Little Tangipahoa River
3/23/2014 Rain Event
Upstream
Downstream
Rainfall
Turbudity (NTU)
Rainfall
Date/Time
45
40
35
30
25
20
15
10
5
0
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
3/23/2014 2:24
3/23/2014 4:48
3/23/2014 7:12

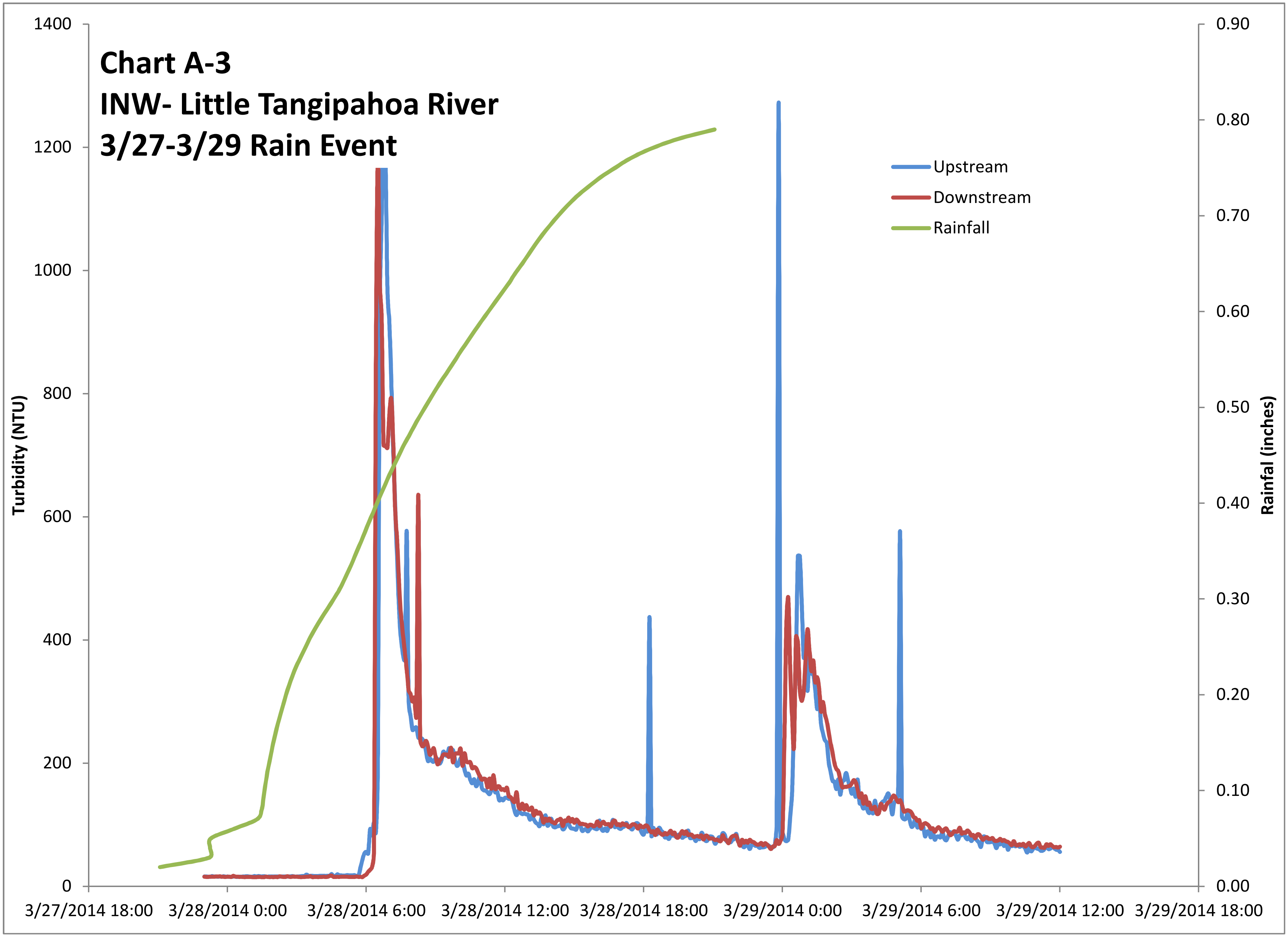
Chart A-3
INW- Little Tangipahoa River
3/27-3/29 Rain Event
Upstream
Downstream
Rainfall
Turbidity (NTU)
Rainfall (inches)
1400
1200
1000
800
600
400
200
0
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3/27/2014 18:00
3/28/2014 0:00
3/28/2014 6:00
3/28/2014 12:00
3/28/2014 18:00
3/29/2014 0:00
3/29/2014 6:00
3/29/2014 12:00
3/29/2014 18:00

PHOTOS

Little Tangipahoa River—McComb, Mississippi

PHOTO A-1—Site conditions during a site reconnaissance.

PHOTO A-2—Silt fence installed along the channel**.**

PHOTO A-3—A view of the channel underneath the bridge.

PHOTO A-4—Downstream sampling location.

PHOTO A-5—Installation of weather resistant boxes.

PHOTO A-6—Downstream sonde installation.

PHOTO A-7—VZCOM installation**.**

PHOTO A-8—Completed console**.**

PHOTO A-9—In-Situ Troll Link installation**.**

PHOTO A-10—Upstream sampling location

.

PHOTO A-11—Upstream sampling location.

PHOTO A-12—Rain-Wise tipping bucket installation.

PHOTO A-13—Upstream sonde installation

.

PHOTO A-14—Upstream console installation with INW tipping bucket.

APPENDIX B

Figures, Charts, and Photographs

Eutacutachee Creek – US- 80, Pelahatchie, Mississippi

FIGURES

MDOT Turbidity Equipment Evaluation
Eutacutachee Creek
Pelahatchie , Mississippi

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Figure B-1
Topo Map

PROJECT NO:	DATE:
13–1106–0026	Sep 2014

MDOT Turbidity Equipment
Evaluation
Eutacutachee Creek
Pelahatchie , Mississippi

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Figure B-2
Aerial Photo

PROJECT NO: 13–1106–0026

DATE: Sep 2014

CHARTS

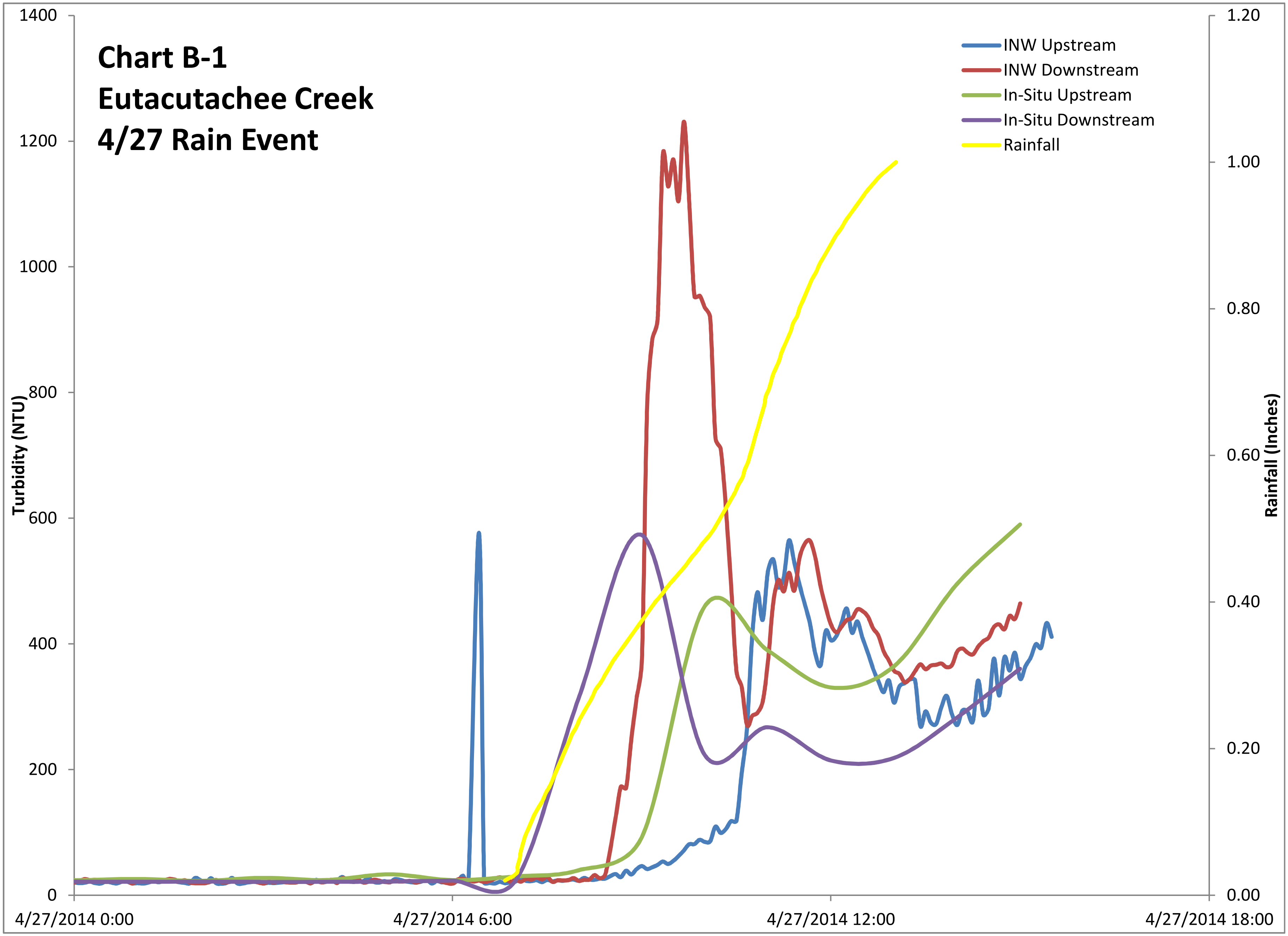


Chart B-1
Eutacutachee Creek
4/27 Rain Event
Turbidity (NTU)
Rainfall (Inches)
INW Upstream
INW Downstream
In-Situ Upstream
In-Situ Downstream
Rainfall
0
200
400
600
800
1000
1200
1400
0.00
0.20
0.40
0.60
0.80
1.00
1.20
4/27/2014 0:00
4/27/2014 6:00
4/27/2014 12:00
4/27/2014 18:00

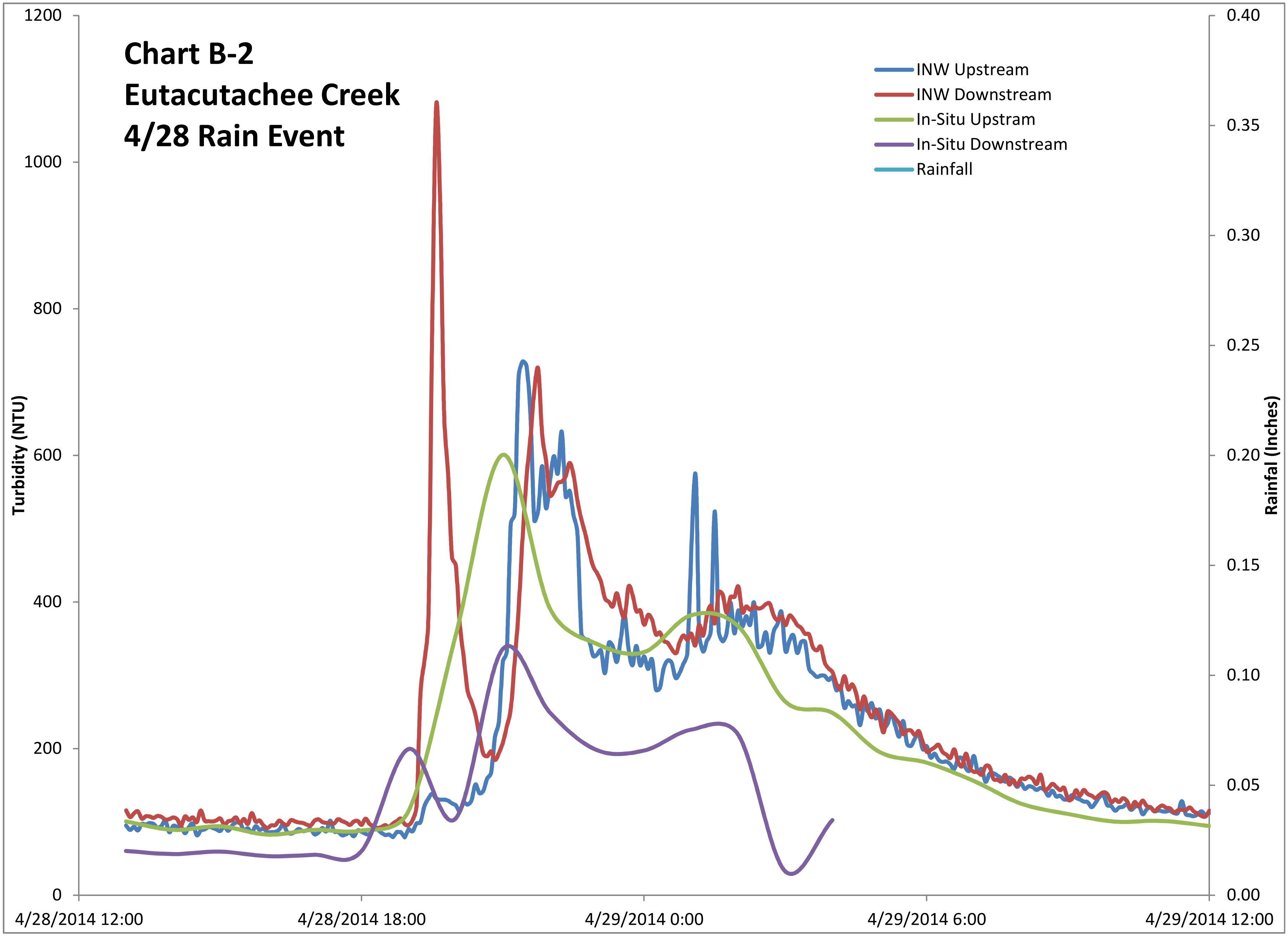


Chart B-2
Eutacutachee Creek
4/28 Rain Event
Turbidity (NTU)
Rainfal (Inches)
INW Upstream
INW Downstream
In-Situ Upstram
In-Situ Downstream
Rainfall
0
200
400
600
800
1000
1200
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
4/28/2014 12:00
4/28/2014 18:00
4/29/2014 0:00
4/29/2014 6:00
4/29/2014 12:00

PHOTOS

Eutacutachee Creek— Pelahatchie, Mississippi

PHOTO B-1—Site conditions during installation

PHOTO B-2—Silt fence installed along the channel.

PHOTO B-3—View from the temporary work bridge

PHOTO B-4—Upstream sampling location

PHOTO B-5—Upstream sampling location.

PHOTO B-6—Completed upstream console.

PHOTO B-7—Pulling cables through PVC at downstream sampling location.

PHOTO B-8—Downstream sampling location**.**

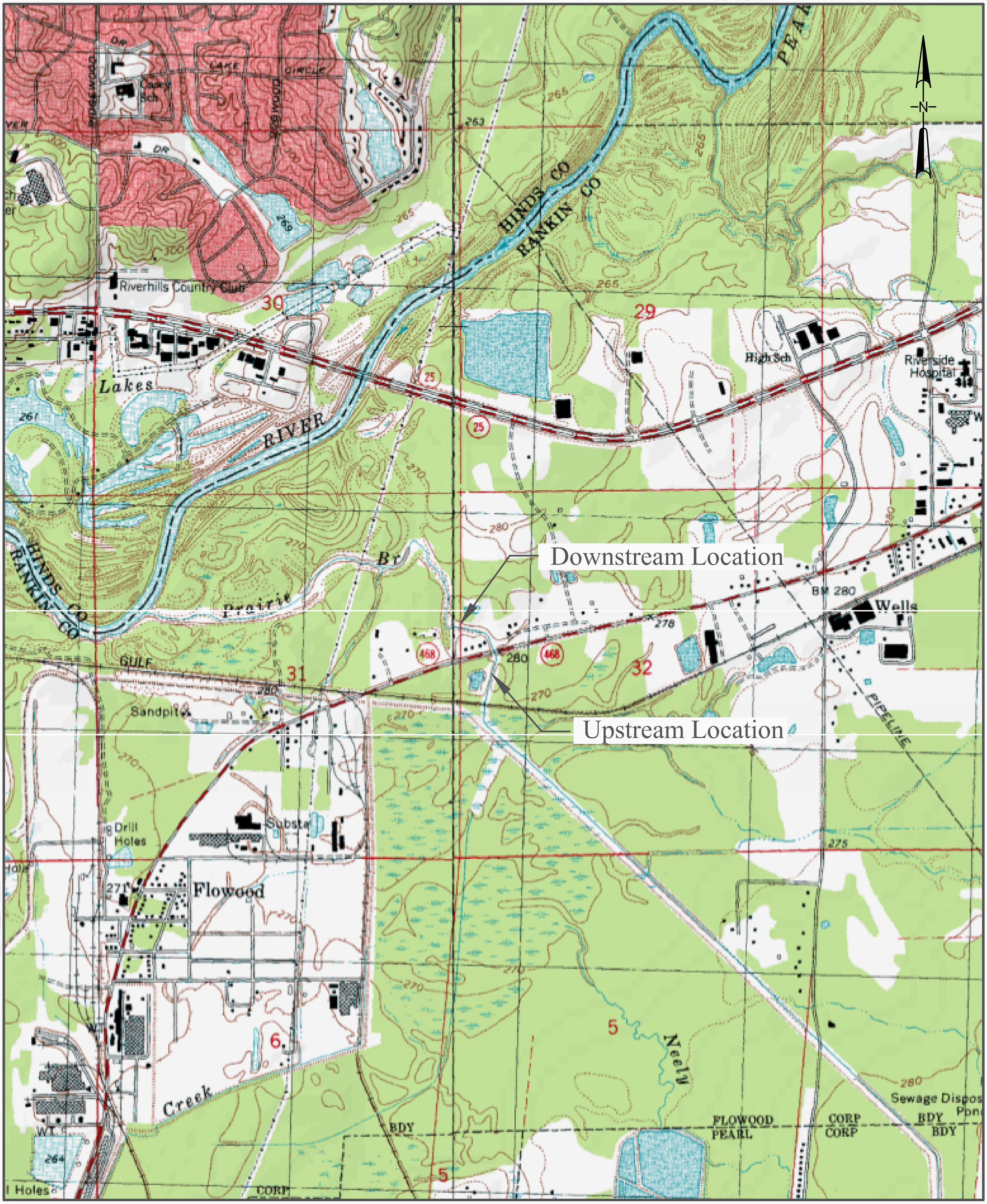
PHOTO B-9—In-Situ installation at the downstream sampling location.

APPENDIX C

Figures, Charts, and Photographs

Prairie Branch, - SR 468, Flowood, Mississippi

FIGURES



MDOT Turbidity Equipment
Evaluation
Prairie Branch
Flowood , Mississippi

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Figure C-1
Topo Map

PROJECT NO: 13–1106–0026

DATE: Sep 2014

MDOT Turbidity Equipment
Evaluation
Prairie Branch
Flowood , Mississippi

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Figure C-2
Aerial Photo

PROJECT NO: 13–1106–0026

DATE: Sep 2014

CHARTS

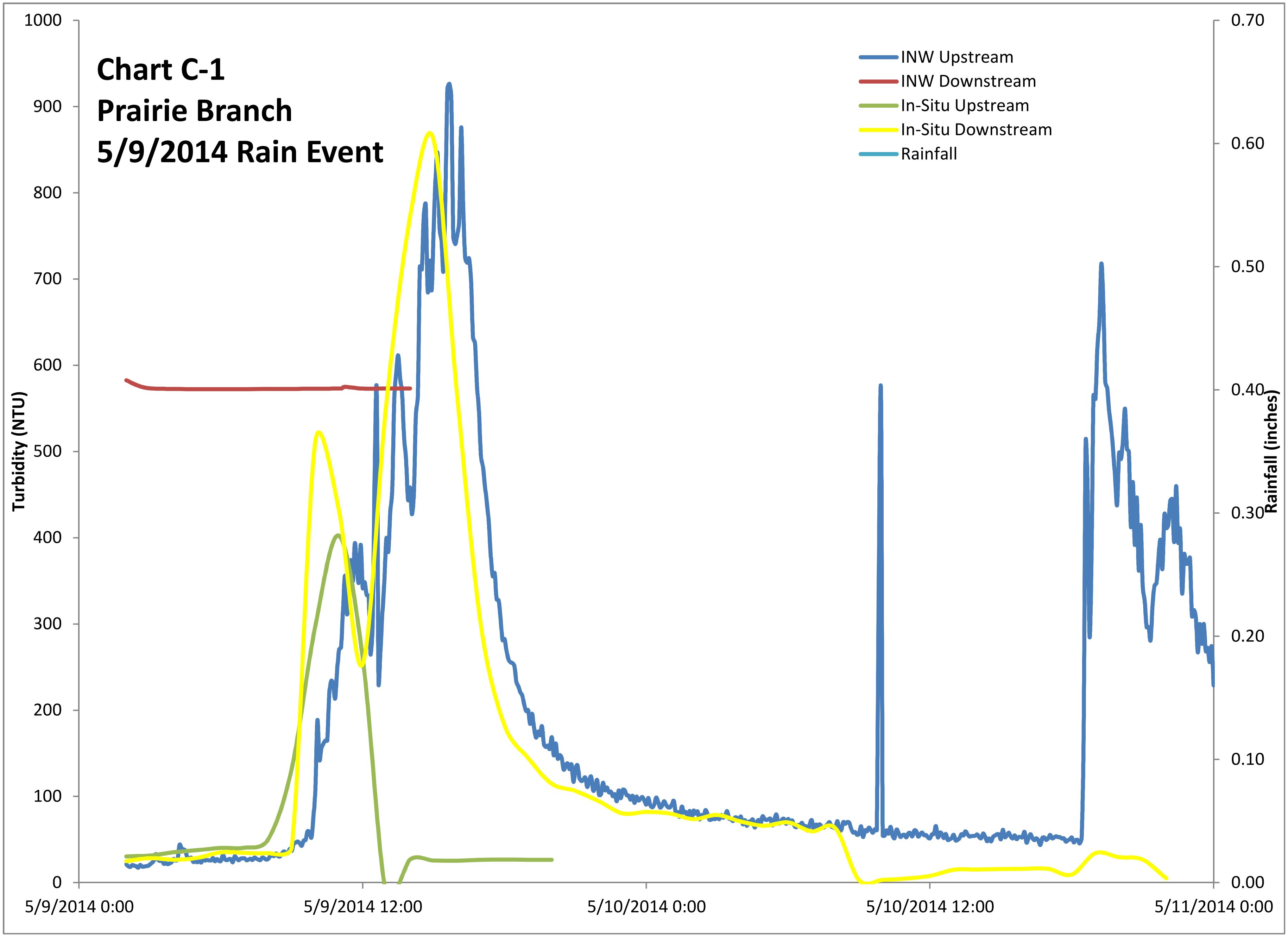


Chart C-1
Prairie Branch
5/9/2014 Rain Event
INW Upstream
INW Downstream
In-Situ Upstream
In-Situ Downstream
Rainfall
Turbidity (NTU)
Rainfall (inches)
1000
900
800
700
600
500
400
300
200
100
0
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
5/9/2014 0:00
5/9/2014 12:00
5/10/2014 0:00
5/10/2014 12:00
5/11/2014 0:00

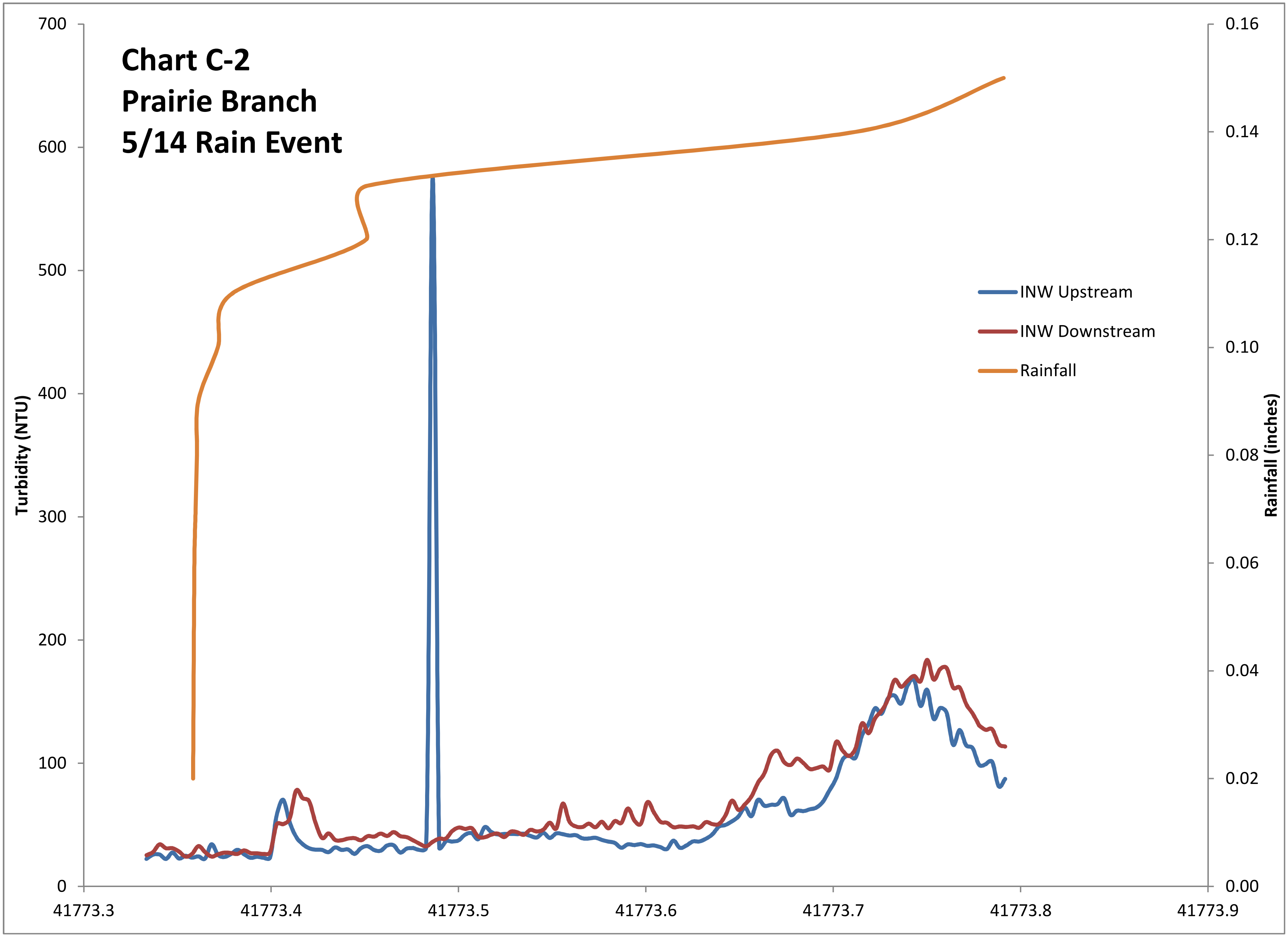


Chart C-2
Prairie Branch
5/14 Rain Event
Turbidity (NTU)
Rainfall (inches)
INW Upstream
INW Downstream
Rainfall
700
600
500
400
300
200
100
0
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
41773.3
41773.4
41773.5
41773.6
41773.7
41773.8
41773.9

PHOTOS

Prairie Branch—Flowood, Mississippi

PHOTO C-1—Downstream sampling location.

PHOTO C-2—Upstream sampling location during equipment retrieval.

PHOTO C-3—Console installation at the downstream sampling location.

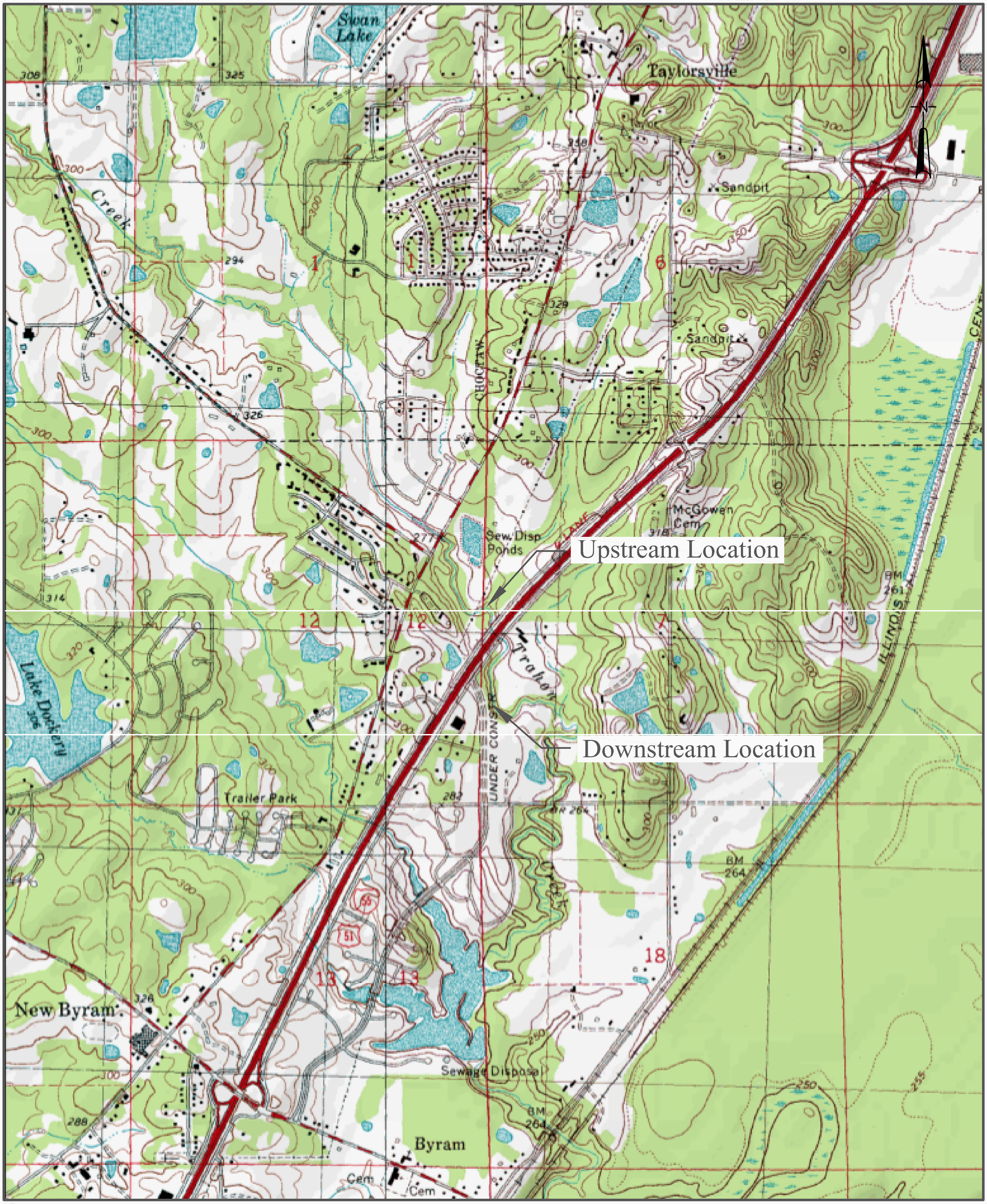
PHOTO C-4—Complete setup at the downstream sampling location.

APPENDIX D

Figures, Charts, and Photographs

Trahon Creek – I-55, Byram, Mississippi

FIGURES



MDOT Turbidity Equipment
Evaluation
Trahon Creek
Byram, Mississippi

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ENGINEERING

Figure D-1
Topo Map

PROJECT NO: 13-1106-0026

DATE: Sep 2014

MDOT Turbidity Equipment
Evaluation
Trahon Creek
Byram , Mississippi

thompson
ENGINEERING

Figure D-2
Aerial Photo

PROJECT NO:	DATE:
13-1106-0026	Sep 2014

CHARTS

Chart D-1
INW-Trahon Creek
6/13 Rain Event

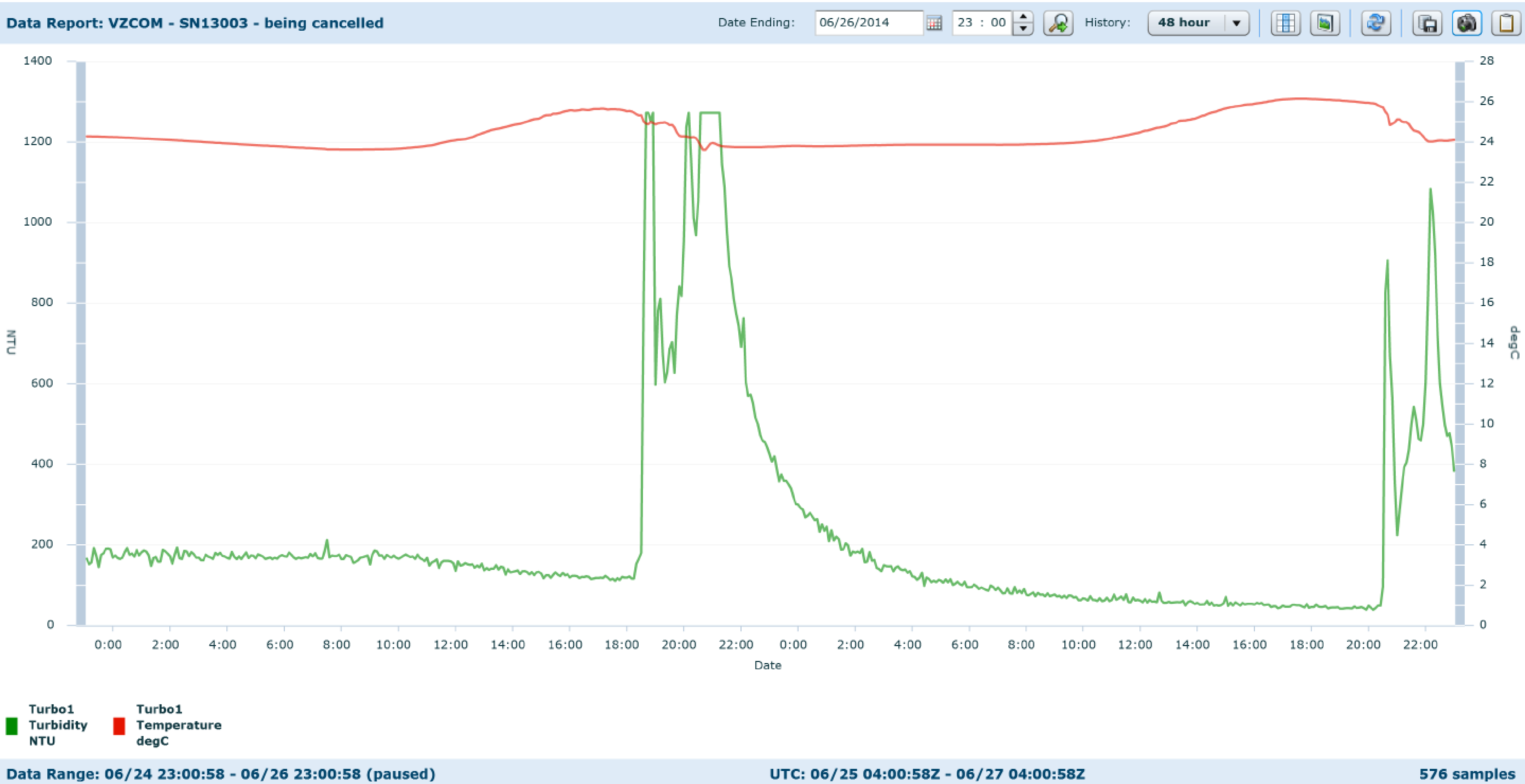
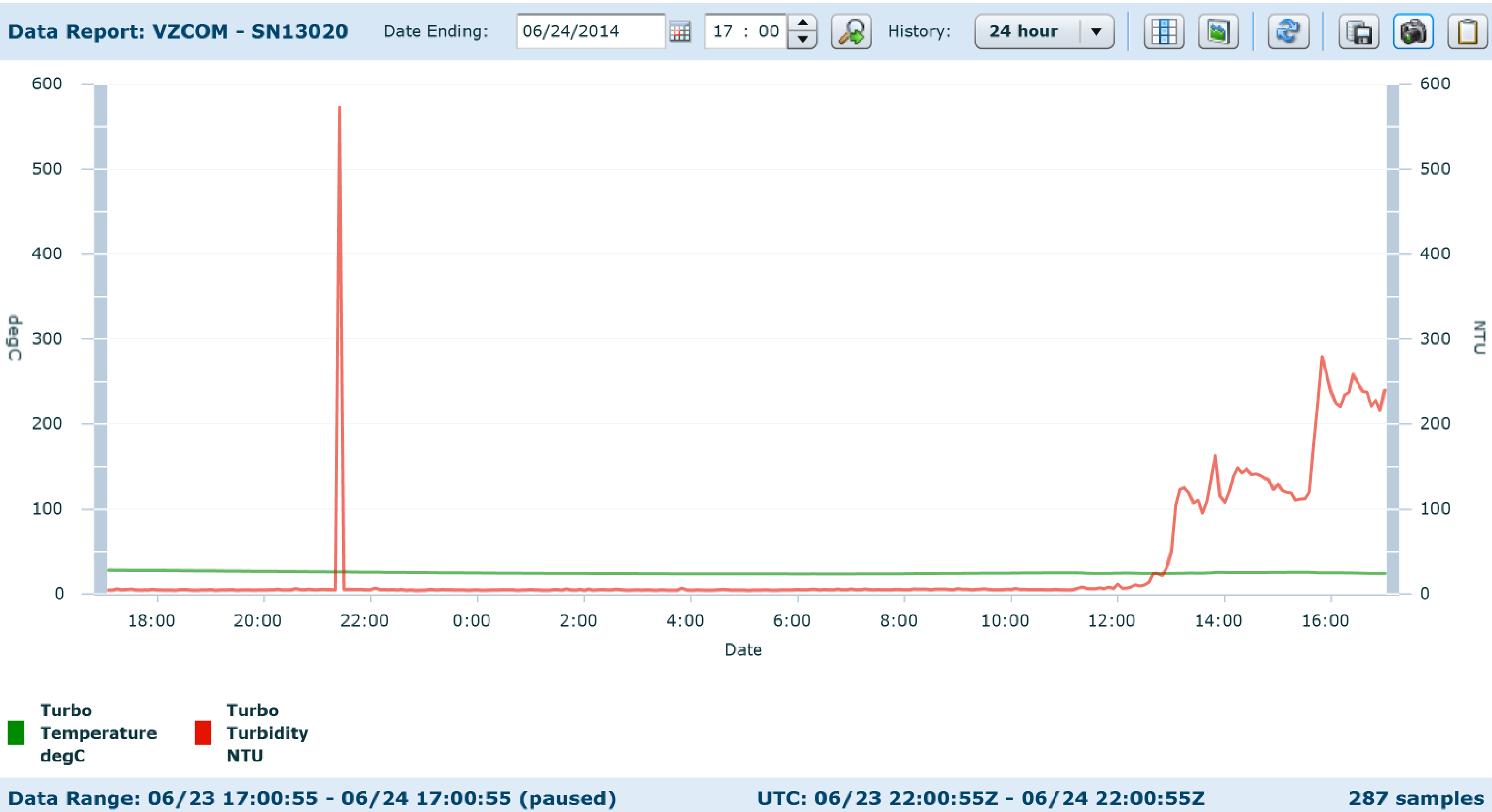


Chart D-2
INW-Trahon Creek
6/24 Rain Event



PHOTOS

Trahon Creek—Byram, Mississippi

PHOTO D-1—Upstream sonde installation.

PHOTO D-2—Upstream sampling location.

PHOTO D-3—Downstream sampling location.

APPENDIX E

Equipment Specification Sheets

INW

Turbo Turbidity Sensor
WITH DATALOGGING

AquiStar™
Data Collection Systems

APPLICATIONS

Monitoring streams and rivers

Monitoring water storage bodies, including stratification studies

Intermediate and final effluent treatment monitoring

Hydrological run-off studies

Ground and bore water analysis

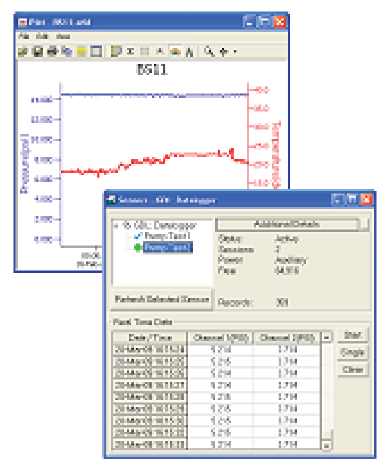
Drinking water filtration efficiency

Industrial process monitoring

Sludge and dredge monitoring

Features

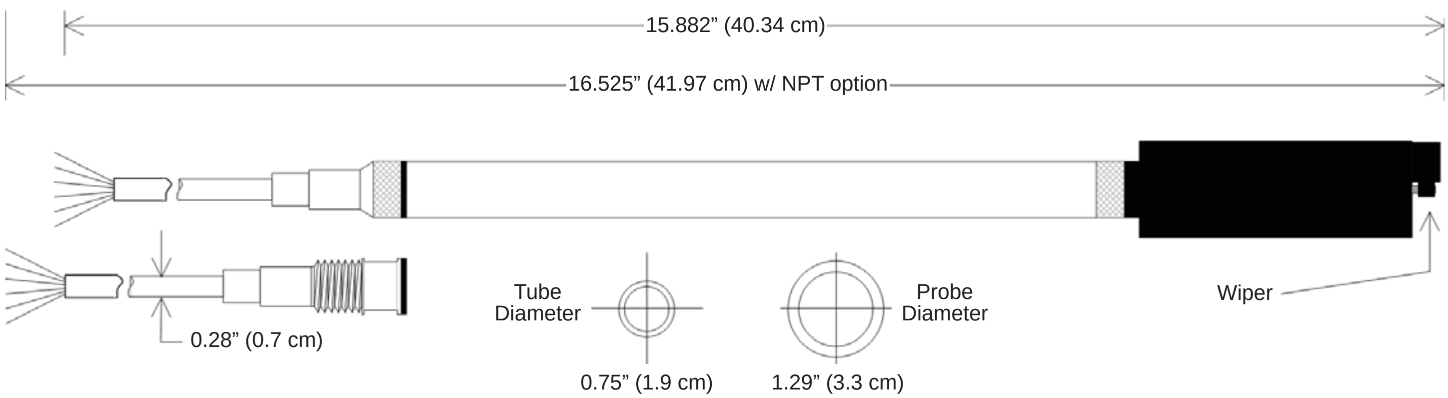
- Measures and records turbidity and temperature
- Modbus® RTU (RS485) and SDI-12 interface — *great flexibility*
- 260,000+ record non-volatile memory — *no data loss in the event of a power failure*
- Wireless connectivity — *radios and/or cellular*
- Programmable warm-up time
- Free, easy-to-use software
- Replaceable wiper blade



FREE AQUA4PLUS SOFTWARE

- Set up flexible recording sequences
- Retrieve data
- Monitor real time data
- View collected data — *tables & graphs*
- Export to spreadsheets and databases with a click of a button

Turbo Turbidity Sensor with Data Logging



GENERAL

Length	15.882” (40.34 cm) w/ cable harness 16.525” (41.97 cm) w/ NPT adapter
Probe Diameter	1.29” (3.3 cm)
Tube Material	Acetal & 316 stainless steel *or* titanium
Probe Material	Composite
Wire Seal Material	Fluoropolymer and PTFE
Submersible Cable	Polyurethane, polyethylene, *or* FEP available
Terminating Connector	Available
Communication	RS485 Modbus® RTU SDI-12 (ver 1.3)
Direct Modbus Read Output	32-bit IEEE floating point
Internal Math	32-bit floating point
Operating Temp. Range	0° C to 40° C
Storage Temp. Range	-20° C to 50° C

LOGGING

Memory	260,000+ records
Log Types	Variable, user-defined, logarithmic, profiled
Programmable Baud Rate	9600, 19200, 38400
Logging Rate	2x/sec maximum
Software	Complimentary Aqua4Plus
Networking	32 available addresses per junction w/ batching capabilities (up to 255)
File Formats	.xls / .csv / .a4d

SENSOR

Measuring Range	0 – 1000 NTU
Accuracy	± 2% or ± 2 NTU @ 25° C (whichever is greater)
Repeatability	± 2% @ 25° C
Temperature Range	0° C to 40° C
Maximum Depth	164 ft (50 m)

POWER

External Power Pack Required	9-15VDC

INW Power Packs available.

Contact INW for details.

SALES & SERVICE

8902 122nd Avenue NE
Kirkland, WA 98033 USA
425-822-4434
FAX 425-822-8384 / info@inwusa.com

1-800-PRO-WELL
WWW.INWUSA.COM

WaveData VZCOM

Environmental Data Meets the Digital World

APPLICATIONS

- Water Resource Monitoring
- Flood Monitoring
- Discharge Monitoring & Alarming
- Tidal Studies
- Aquifer Resource Managment
- Stream-Gauging

Low Power Modem

Features

- Manage modem and sensor configurations (examples: sensors installed & collection frequency) over the web
- Field test button ensures proper installation
- Low power consumption for long battery life
- Intelligent power modes & charging circuit
- Works with all INW Smart Sensors
- 4MB of redundant data storage
- Powerful web-based management software
- CSV Service Option available to integrate with 3rd party data management & modeling software

SPECIFICATIONS

Housing	Aluminum
Dimensions	4.86"L x 1.2"H x 2.5"W (12.3cm L x 3.0cm H x 6.6cm W)
Weight	0.5 lbs. (0.23kg)
RF Sensitivity	
1900 MHz (CDMA)	-108dBm
800 MHz (CDMA)	-108dBm
Communication	Modbus/RS485
Operating Temperature	-20° C to 50° C
Storage Temperature	-40° C to 80° C
Certifications, Approvals,Compliance	RoHs, FCC, IC, CDMA Carrier Approval
Cellular Network	Verizon
Logging	Logs internal temperature, Voltage, RSSI, up to four INW sensors
Output Voltage	12 VDC switched for powering sensors (500 mA)
Diagnostics	Two colored LEDs for troubleshooting

POWER OPTIONS

Wall (Included)	110 Volt AC	
	18 VDC - 10 A/HR (18 Watts)	
Solar Option	1.4 A/HR Sealed Lead Acid	
	10 Watt Panel with 10' Cord	
High Capacity Option	Lithium AA	16.8 VDC - 1-Year Life (2)
		2.6 A/HR
	Lithium D (1)	16.8 VDC - 5-Year Life (2)
		14 A/HR

POWER OPTIONS

18 VDC Wall Supply

10 Watt Solar Supply

Primary Lithium Pack (4 AA)

(1) Class 9 Hazardous Material - Ground shipping ONLY without certification.
(2) Based on 15 minute data collection with four call-ins per day.

SALES & SERVICE

8902 122nd Avenue NE
Kirkland, WA 98033 USA
425-822-4434
FAX 425-822-8384 / info@inwusa.com

1-800-PRO-WELL
WWW.INWUSA.COM

IN-SITU

In-Situ Inc.

Innovations in
Water Monitoring

TROLL® 9500 Multiparameter Instrument

The powerful, portable TROLL 9500 Water Quality Instrument is designed for groundwater and surface water monitoring. The unit houses up to nine water quality sensors, internal power, and optional data logger.

Lower Total Cost of Ownership

- Instrument saves time and money by offering long-lasting internal power, automated low-flow sampling, and telemetry accessibility.
- Field-proven sensors and antifouling system reduce maintenance and site visits.
- Intuitive Win-Situ® 4 Software and Flow-Sense Software improve efficiency by simplifying data collection and management.

Reliable, Accurate Operation

- Instrument operates in fresh, waste, and marine waters.
- Instrument offers proven performance. Rigorous third-party testing shows that the TROLL 9500 delivers consistent results.
- Sensors are factory calibrated with NIST®-traceable standards (where applicable).

Outstanding Customer Service

- Free, 24/7 technical support
- Seven-day service for maintenance and calibration (U.S.A. only)

Logging Models

- ***LTS:*** LTS stands for "Level, Temperature, and one additional Sensor," such as conductivity, dissolved oxygen (DO), or pH.
- ***Professional:*** This unit offers the highest value for most applications. Instrument allows for several sensors, including conductivity/salinity, DO, ORP, pH, temperature, or depth.
- ***Professional XP:*** The most capable TROLL 9500 offers features available on the Professional and supports XP or "Extended Parameter" sensors—turbidity, ammonium, chloride, or nitrate.

Non-Logging Models

- ***Profiler:*** Ideal for sampling or vertical profiling, this unit is similar to the Professional, but does not include memory or logging capabilities. Data can be logged to a RuggedReader® Handheld PC or laptop.
- ***Profiler XP:*** This unit offers the same features as the Profiler with the option to use XP sensors.

Applications

- Coastal deployments—estuaries and wetlands
- Environmental monitoring and spot checking
- Low-flow groundwater sampling
- Remediation and mine water monitoring
- Stormwater management
- Vertical profiling

TROLL® 9500 Water Quality Sensors

Customizable for Your Application

Choose from several field-ready sensors. The selected sensor set will determine the diameter of the TROLL 9500—sub-2 inch or sub-4 inch.

- ***Barometric pressure:*** Use this sensor to compensate water level and DO values.
- ***Conductivity:*** Characterize water quality in actual conductivity, specific conductivity, salinity, TDS, or specific gravity.
- ***DO:*** Choose from the optical Rugged Dissolved Oxygen (RDO®) Sensor or Clark cell.
- ***Level/Pressure:*** Choose from non-vented and vented sensors that are available for several ranges.
- ***Nutrients:*** Choose from ion-selective electrodes for ammonium, chloride, or nitrate.
- ***pH or pH/ORP:*** Extend field use with these durable sensors. The re-buildable pH sensor outlasts traditional sensors.
- ***Temperature:*** Compensate conductivity, DO, pH, and nutrient data with this fast, accurate sensor.
- ***Turbidity or Turbidity/Level:*** Comply with ISO standards. The turbidity sensor uses ISO 7027 method. Optional wiper is available for high-fouling sites or for lengthy deployments.

Optical RDO Sensor

Breakthrough RDO technology surpasses Clark cell performance by eliminating hydration effects, membranes, electrolyte solution, and stirring.

- ***Rugged performance:*** Wiper-free design excels in demanding environments. Abrasion-resistant foil withstands fouling, high sediment loads, and rapid flow rates. No photobleaching effects.
- ***Automatic setup:*** RDO Cap with pre-loaded calibration coefficients simplifies setup and eliminates programming errors.
- ***Accurate results:*** Operates with low drift over long-term deployments. Excels in hypoxic conditions. Responds quickly and maintains stable response.
- ***Long-lasting calibration:*** Deploys for several months if sensor fouling is minimal and if the foil is not damaged or removed.
- ***Minimal interferences:*** Sensor is unaffected by sulfides, sulfates, hydrogen sulfide, carbon dioxide, ammonia, pH, or chloride.
- ***Fast response:*** Ideal for vertical profiling and dynamically changing conditions.

TROLL 9500 Accessories

TROLL® Shield Antifouling System

The TROLL Shield Guard slows biofouling on TROLL 9500 sensors. The guard extends instrument deployments in coastal environments and at high-fouling sites by up to six weeks.

DO Field Bubbler Kit

For accurate results, use the DO Bubbler Kit for air-saturated water calibrations. The kit reduces time spent on calibration setup.

Calibration Solutions

From easy-to-use Quick Cal Solution to NIST®-traceable standards, In-Situ supplies calibration solutions required to get accurate results. Call for details or visit ***www.in-situ.com***.

RuggedCable® Systems, Reels, & Well Accessories

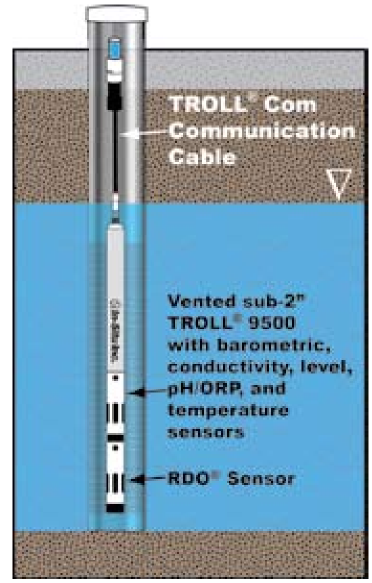
RuggedCable Systems endure harsh environments and last for years. Titanium twist-lock connectors and Kellems® grip are included. Vented or non-vented cable is available in either Tefzel® or polyurethane. Order customized lengths up to 1,219 m (4,000 ft). Steel or plastic reels make deployment of long cables manageable. Ask us about well-docking accessories.

Real-Time *Monitoring for Remediation*

Conduct ISCO, ISCR, Biosparging, Air Sparging & More

The TROLL® 9500 Instrument supports real-time measurement of performance indicators, which allows for a dynamic work strategy per the EPA Triad Approach to site remediation. You can adapt to changing conditions as new data becomes available. This allows you to complete projects more quickly and at a lower cost than when using traditional approaches. With the TROLL 9500, you can:

- Deploy a sub-2 inch instrument and monitor DO with the RDO® Sensor, conductivity, pH/ORP, temperature, and barometric pressure. With the S2XP Restrictor, you can also log water level.
- Deploy in harsh conditions. The corrosion-resistant housing is suitable for many remediation applications.
- Reduce grab sampling and labor costs while improving safety when working with treatment chemicals.
- Improve performance monitoring and reduce maintenance and calibration time with durable sensors.
- Connect to the TROLL® Link Telemetry System for remote access and external power.



TROLL *9500 Low-Flow Sampling System*

You can use the TROLL 9500 System with Flow-Sense Software to conduct low-flow purging and sampling. You will collect representative samples, minimize contaminant volatilization, and reduce hazardous waste disposal. To improve efficiency in the field, the system:

- Automates collection of well and pumping information
- Monitors and records stabilization of key water quality parameters
- Automatically generates defensible calibration and sample reports that conform to federal and regional regulations
- Eliminates transcription time and errors

Automated Test Setup

Flow-Sense Software retains all project information—well data, pump performance specifics, tubing details, pumping rate, stabilized drawdown, and parameter stabilization criteria. You can quickly access site information at subsequent sampling events without reentering data.

Win-Situ® Sync Software automatically copies well records and data between a computer and a RuggedReader® Handheld PC.

Automated Data Collection

Stabilization criteria are set for each monitored parameter. Data collection intervals are defined by time or pumped volumes. During sampling, software calculates and displays variance and targets for each parameter. Data is logged at pre-determined intervals and stabilization is achieved when readings meet variation criteria. In addition, you can view data numerically or graphically.

Automated Test Report Generation

After stabilization, stored data can be exported into Excel®. Flow-Sense Software automatically generates full calibration and sample reports that conform to federal and regional regulations. To save time, simply reuse templates at subsequent sampling events.

TROLL® 9500 Multiparameter Instrument

General	***TROLL** 9500 Water Quality Instrument*				
Operating temp.	-5 to 50° C (23 to 122° F)				
Storage temp.	-40 to 65° C (-40 to 140° F)				
Dimensions & weight	4.7 cm (1.85 in) OD x 55.25 cm (21.75 in). With twist-lock hanger: 56.52 cm (22.25 in). Restrictor: 8.9 cm (3.5 in) OD x 21 cm (8.25 in) long; 1.9 kg (4.2 lbs)				
Wetted materials	PVC, 316L stainless steel, titanium, Acetal, Viton®, nylon. Cable: Tefzel® or polyurethane				
Water tightness rating	IP68 with all sensors and cable attached. Battery compartment: IP67 without the battery cover or cable attached				
Output options	RS485/RS232; SDI-12 (optional with SDI-12 adapter); ASCII streaming mode or binary command				
Power	External: 9-16 VDC (optional). Internal: 2 user-replaceable D batteries (use either alkaline or matched pair of lithium). Use only Saft LSH-20 3.6V lithium D cells. Use of any other battery will void the warranty.				
Logging					
Data logging	16 programmable tests (defined, scheduled to run, or stored). Logging modes: Linear, Linear Average, Event				
Memory	4 MB (222,000 data records[1])				
Standard Sensors	*Accuracy*	*Range*	*Depth Rating*	*Response Time*	*Methodology*
Barometric pressure	±0.3% FS	16.5 psia	Meets highest rating	< 30 sec per 30 m (100 ft) of cable	Silicon strain gauge
Level, Depth, Pressure	±0.1% FS or better Sensor accuracy: -5 to 50° C	15, 30, 100, or 300 psi	*Non-vented* 30 psia: 10.90 m (35.76 ft) 100 psia: 60.11 m (197.2 ft) 300 psia: 200.7 m (658.6 ft) *Vented* 15 psig: 10.55 m (34.61 ft) 30 psig: 21.10 m (69.21 ft) 100 psig: 70.32 m (230.7 ft) 300 psig: 211.0 m (692.1 ft)	Instantaneous in thermal equilibrium	Silicon strain gauge (non-vented or vented)
Conductivity	Low: ±0.5% or 2 µS/cm High: ±0.5% + 2 µS/cm	Low: 5 to 20,000 µS/cm High[2]: 150 to 112,000 µS/cm	Low: Meets highest rating High: Meets highest rating	Low: Instantaneous High: Instantaneous	Std. Methods 2510, EPA 120.1 Std. Methods 2510, EPA 120.1
Dissolved oxygen *RDO® Sensor[3, 4]*	±0.1 mg/L ±0.2 mg/L ±10% of reading	0 to 8 mg/L 8 to 20 mg/L 20 to 50 mg/L	150 psi from 0 to 50° C 300 psi @ 25° C	T90: < 45 sec. T95: < 60 sec. T90: < 45 sec. T95: < 60 sec. T90: < 45 sec. T95: < 60 sec.	*EPA-approved In-Situ Methods* 1002-8-2009, 1003-8-2009, 1004-8-2009
Clark cell	±0.2 mg/L	0 to 20 mg/L; 0 to 200% saturation	246 m (807 ft)	1-mil membrane: 1-2 min @ 25° C 2-mil membrane: 90 sec to 3 min	Std. Methods 4500-O G, EPA 360.1
pH (single)[5] or pH/ORP (combo)[5]	pH: ±0.1 pH unit ORP: ±5.0 mV	pH: 0 to 12 pH units ORP: ±1400 mV	pH: 211 m (692 ft) pH/ORP: 211 m (692 ft)	pH: < 15 sec, pH 7 to pH 4 ORP: < 15 sec	pH: Std. Methods 4500-H^+, EPA 150.2 ORP: Std. Methods 2580
Temperature	±0.1° C	-5 to 50° C (23 to 122° F)	Meets highest rating	< 30 sec	EPA 170.1
Extended Parameter (XP) Sensors					
Ammonium (NH_4^+)	±10%	0.14 to 14,000 ppm N	14 m (46 ft)	T98: < 60 sec, 1.4 to 14 ppm N	Std. Methods 4500-NH_3 D, EPA 350.3
Chloride (Cl^-)	±15%	0.35 to 35,500 ppm Cl	70 m (231 ft)	T98: < 60 sec, 3.54 to 35.45 ppm Cl	Std. Methods 4500-Cl^- D
Nitrate (NO_3^-)	±10%	0.14 to 14,000 ppm N	14 m (46 ft)	T98: < 60 sec, 1.4 to 14 ppm N	Std. Methods 4500-NO_3 D
Turbidity	±5% or 2 NTU/FNU	0 to 2,000 NTU/FNU	105 m (346 ft)	Instantaneous (5 sec for first reading)	ISO 7027
Warranty	TROLL 9500 and all sensors (excluding RDO & ISE sensors) come with a 1-year warranty. RDO Sensor: 3-year warranty. ISE sensors: 90-day warranty. RuggedCable® System: 2-year warranty.				
Notes	[1]A single data record includes time stamp, temperature, RDO, pH, and conductivity logged in Linear or Linear Average mode. [2]Full operating range: 70 to 200,000 µS/cm. [3]Full operating range: 0 to 50 mg/L. [4]Known interferences: Alcohols >5%; hydrogen peroxide >3%; sodium hypochlorite (commercial bleach) >3%; gaseous sulfur dioxide; gaseous chlorine; organic solvents (e.g., acetone, chloroform, methylene chloride, etc.), which may swell the sensing element (foil matrix) and destroy it. [5] pH sensor and pH/ORP sensor temperature range: 0 to 50° C.				

In-Situ Inc.

Call to purchase or rent—www.in-situ.com
221 East Lincoln Avenue, Fort Collins, Colorado, U.S.A. 80524
1-800-446-7488 (toll-free in U.S.A. and Canada)
1-970-498-1500 (U.S.A. and international)

In-Situ Inc.

Innovations in Water Monitoring

TROLL® *Link Telemetry Systems*

Real-Time Data Access

In-Situ® TROLL Link Telemetry Systems offer reliable, secure access to remote site data 24 hours a day. Use these systems for a variety of applications—long-term aquifer monitoring, stream and tide gaging, flood warning, storm surge monitoring, and water monitoring networks.

- **Save time and money**—Quickly access data while reducing site visits, labor costs, and travel expenditures.
- **Access real-time data from any location**—Choose from satellite, cellular, or radio options to ensure communication with your sites. Event-driven sampling and real-time alarm notifications alert you to changing conditions. View and analyze data from anywhere by using Win-Situ® Plus Software or by using the secure In-Situ Data Center web site.
- **Network multiple wells or sites**—Build wireless monitoring networks with Banner MultiHop Radios, lower data service fees, and reduce the need for a telemetry system at each site.
- **Reduce power consumption**—Eliminate the need for on-site line power by combining low-power telemetry systems with energy-saving In-Situ instruments. Solar power preserves probe battery life.

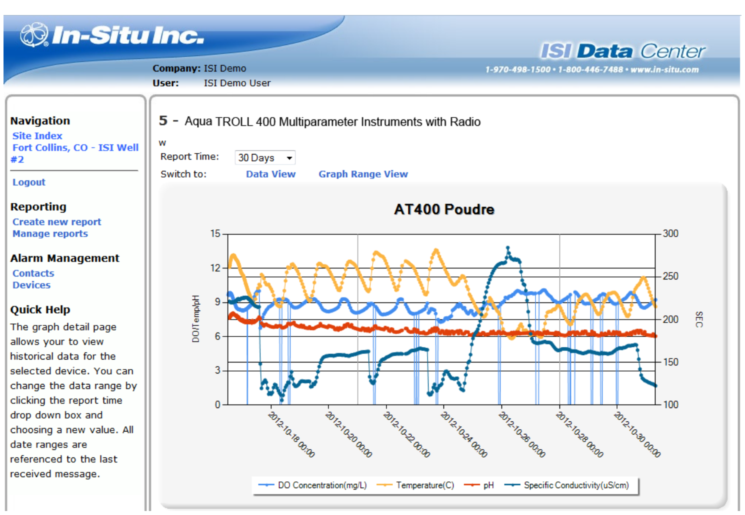
Remote Site Control

View data when you need to and configure equipment without site visits.

TROLL Link 100 System for Direct Access

This system operates on GSM/GPRS networks and offers direct connection via TCP/IP and dial-up to many In-Situ probes. Use the TROLL Link 100 System and Win-Situ Plus Software to:

- Remotely configure instruments and the telemetry system.
- Remotely extract data from instruments.
- Set up alarms and receive notifications of user-defined events via SMS or email (single user/single parameter).
- Provide external power to attached instruments.



TROLL Link 101 & 201 Systems for Web-Based Access

These systems offer access to many In-Situ probes with the In-Situ Data Center. The TROLL Link 101 System transmits data via GSM/GPRS networks. The TROLL Link 201 System transmits data via the Iridium Satellite Network. Use these systems to:

- Remotely configure the telemetry system.
- Provide access to real-time data for large user groups.
- Set up alarms and receive notifications of events via SMS, email, or phone call (multiple users/multiple parameters).
- Conduct event sampling and automatically increase data transmission during an event.
- Provide external power to attached instruments.

MultiHop Radios Lower Operating Costs

With Banner Engineering MultiHop Data Radios, you can build wireless water monitoring networks that use In-Situ instruments, provide real-time data, improve project efficiency, and reduce expenses. Radios can be networked with In-Situ instruments into a TROLL Link Telemetry System. Call for details or visit ***www.in-situ.com***.

TROLL® Link Telemetry Systems

Selection Guide & Specifications

Communications	**TROLL** *Link 100**	**TROLL** *Link 101***	**TROLL** *Link 201***
Technology	Cellular—GSM/GPRS	Cellular—GSM/GPRS	Iridium Satellite Network
Frequency Range	Quad-Band 850, 900, 1800, 1900 MHz	Quad-Band 850, 900, 1800, 1900 MHz	1616 to 1626.5 MHz
Integrates with Radio	No	Yes	Yes
Data Access Mode			
TCP/IP; Dial-Up/CSD; SMS Data	Yes	No	No
In-Situ Data Center	No	Yes	Yes
Alarm Notifications			
SMS and Email	Yes	Yes	Yes
Phone	No	Yes	Yes
Single Contact; Single Parameter	Yes	Yes	Yes
Multiple Contacts; Multiple Parameters	No	Yes	Yes
Probe Options			
	Aqua TROLL® 100 & 200 BaroTROLL® & Rugged BaroTROLL Level TROLL® 300, 500, & 700 Rugged TROLL® 200	Aqua TROLL 100, 200, & 400 BaroTROLL & Rugged BaroTROLL Level TROLL 300, 500, & 700 RDO® PRO Probe Rugged TROLL 200 TROLL 9500	Aqua TROLL 100, 200, & 400 BaroTROLL & Rugged BaroTROLL Level TROLL 300, 500, & 700 RDO PRO Probe Rugged TROLL 200 TROLL 9500

TROLL *Link Telemetry Specifications*	
Enclosure	NEMA 4X/IP67
Operational Temp. Range	Cellular: -20° to 60° C (-4° to 140° F) Satellite: -40° to 70° C (-40° to 158° F)
Dimensions (WxHxD)	25.4 x 30.5 x 12.7 cm (10 x 12 x 5 in.)
Weight	6.8 kg (15 lbs) — Includes battery
Communication Options	Satellite; Cellular (GSM/GPRS)
Power Supply Options	• 1-W solar panel (direct to system) • 10-W solar panel (into External Battery Kit with charge controller) • 20-W solar panel (into External Battery Kit with charge controller) • 12 V, 7 Ah sealed lead-acid battery kit with charge controller
Warranty	1 year

TROLL® Net Hub Networks Multiple Probes

- Networks up to eight devices into one telemetry system
- Maximum cable length of 1,219 m (4,000 ft) per Modbus/RS485 protocol
- Uses 9-36 VDC power source
- Passes power to attached probes when connected to external power

TROLL *Net Hub Specifications*	
Models	4-port bulkhead; 8-port bulkhead; 4-port strain relief; 8-port strain relief. Models with strain relief are used with stripped-and-tinned cables.
Enclosure	NEMA 4X/IP67
Operational Temp. Range	-40° to 60° C (-40° to 140° F); 95% relative humidity
Storage Temp. Range	-40° to 85° C (-40° to 185° F); 95% relative humidity, non-condensing
Dimensions (WxHxD)	16 x 16 x 9.04 cm (6.3 x 6.3 x 3.56 in.)
Weight	• 4-port bulkhead: 694 g (1.53 lbs) • 8-port bulkhead: 838 g (1.85 lbs) • 4- and 8-port strain relief: 632 g (1.39 lbs)
Power Requirements	9-36 VDC (refer to instrument documentation for cable length and voltage limitations)
Current Draw	• 20 µA sleep mode (without instrument load) • 60 mA wake mode (without instrument load)
Warranty	1 year

* Discrete Input/Counter included. **Optional Discrete Input/Counter available.
Specifications are subject to change without notice.

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1-970-498-1500 (U.S.A. and international)

YSI

NEW

600XL V2-1 and 600XLM V2-1 Sondes

Measure multiple parameters simultaneously

Left: 600XL V2-1 with two-piece probe guard; right: 600XLM V2-1 sonde with optical DO sensor (bottom) and batteries (top)

The YSI 600XL V2 and YSI 600XLM V2 compact sondes measure multiple parameters simultaneously, including:

Temperature	Specific Conductance
Conductivity	Salinity
pH	Resistivity
ORP	TDS
Depth or Level	

Both sondes have one optical port, allowing for measurement of an additional parameter with one of the following optical sensors:

ROX™ Optical Dissolved Oxygen
Turbidity
Chlorophyll
Blue-Green Algae (freshwater or marine)
Rhodamine WT

Each optical sensor has an integrated anti-fouling wiper which prolongs deployment times (thus reducing operating costs) and improves the quality of data.

Economical Logging and Spot Sampling System

The YSI 600XLM V2 is an economical logging system for long-term, *in situ* monitoring, profiling, and spot sampling. It will log all parameters at programmable intervals and store 150,000 readings. At one-hour intervals, the instrument will log data for about 75 days utilizing its own power source. The 600XL V2 can also be used in the same manner with user-supplied external power.

- **Either sonde fits down 2" wells (1.65" OD)**
- **Optical sensor port provides a multipurpose platform**
- **Field-replaceable sensors for quicker maintenance**
- **Easily connects to data collection platforms**
- **Anti-fouling wipers on optical sensors extend deployment times**
- **Compatible with YSI 650 Multiparameter Display System**
- **Flow cell available for pump-through applications**
- **Horizontal measurements in very shallow waters**

Connect with Data Collection Platforms

Either sonde can easily connect to the YSI 650 handheld logger/display, YSI 6200 DAS (Data Acquisition System), web-enabled YSI EcoNet® or your own data collection platform, via SDI-12, for remote and real-time monitoring applications.

Pure Data for a Healthy Planet.®

Multiparameter sampling or logging in a compact sonde for ground water, dredging, and spot sampling applications

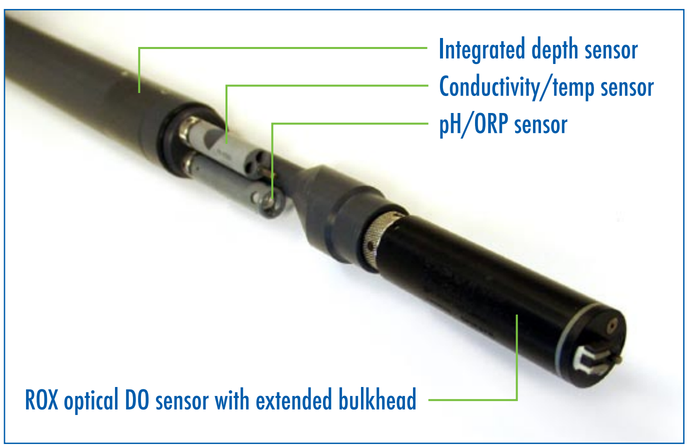
Sonde Features

- **ROX™ Optical DO:** An extremely durable DO sensor with excellent stability, insensitivity to hydrogen sulfide, and integrated anti-fouling wiper, which results in the longest deployment times while reducing operating costs.
- **Field-Replaceable Sensors** allow users to quickly and easily replace damaged sensors in the field or reconfigure a sonde for multiple applications by switching optical sensors.
- **Power Management:** Battery life is 34 days at a 15-minute interval or 75 days at a 1-hour interval with optical DO sensor installed.
- **Key Applications:** ground water monitoring, dredging, spot sampling, education, and long-term monitoring studies.

YSI 600XL V2-1 and 600XLM V2-1 Sonde Specifications

Available Sensors*		Temperature, conductivity, pH, ORP, optional depth (shallow, medium, or shallow vented), and one optical sensor (dissolved oxygen, turbidity, chlorophyll, rhodamine, or blue-green algae)
Operating Environment		
	Medium	Fresh, sea, or polluted water
	Temperature	-5 to 50˚C
	Depth	0 to 200 ft (61 m) for sonde
Storage Temperature		-40 to 60˚C for sonde and sensors except pH and pH/ORP -10 to 60˚C for pH and pH/ORP sensors
Material		PVC, stainless steel
Diameter		1.65 in (4.19 cm)
Length	600XL V2	25.1 in (63.8 cm) without depth sensor; 27.1 in (68.8 cm) with depth and no bottom weight
	600XLM V2	28.5 in (72.4 cm) without depth sensor; 30.5 in (77.5 cm) with depth and no bottom weight
Weight	600XL V2	1.96 lbs. (0.87 kg) with depth and no bottom weight
	600XLM V2	2.15 lbs. (1.05 kg) with depth and no bottom weight
Communications		RS-232C, SDI-12
Memory		384 kb (150,000 individual parameter readings)
Power	600XL V2	External 12 V DC
	600XLM V2	4 AA Alkaline batteries or external 12 V DC
Battery Life		Approximately 30 days at 20˚C at a 15-minute logging interval with optical DO, temperature, conductivity, pH/ORP, and depth sensors operative

** Note: Rapid Pulse™ polarographic-style DO sensor is not available on the V2 sondes. Please refer to the 600XL or 600XLM sondes.*



Standard Accessories

- Two-piece probe guard with bottom weight
- Carrying case
- 8, 25, 50, and 100 ft cables (other lengths available)
- Long calibration cup
- EcoWatch® software
- Maintenance kit
- Flow cell kit (optional)

To order, or for more information, contact YSI
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Yellow Springs, Ohio Facility

CE

YSI incorporated
Who's Minding the Planet?®

YSI 6136 Turbidity Sensor

Accurate, in situ *turbidity measurements*

The 6136 is a fouling-resistant, wiped sensor designed to seamlessly integrate – using no external interface hardware – with all YSI sondes that contain an optical port. It provides accurate, *in situ* measurement of turbidity in fresh, brackish, and sea water, and features an improved mechanical self-wiping capability for long-term monitoring, which helps ensure proper turbidity measurements.

YSI 6136 Optical Turbidity Sensor

- ***In situ* monitoring**
- **Self-cleaning sensor for long-term deployment**
- **Field-replaceable**

Take Advantage of YSI's New V2 Sondes

Expand your optical monitoring capability and upgrade your 6820, 6920, or 6600. V2 upgrades increase the number of optical ports on your sonde, allowing for measurement of additional optical sensors including:

- **Turbidity**
- **Blue-Green Algae - Phycocyanin (for freshwater applications)**
- **Blue-Green Algae - Phycoerythrin (for marine applications)**
- **ROX™ Optical Dissolved Oxygen**
- **Chlorophyll**
- **Rhodamine**

Upgrades are available from YSI Authorized Service Centers. Contact YSI for details.

Pure Data for a Healthy Planet.®

Accurate, **in situ** *turbidity measurement*

Sensor performance verified*

ETV

The performance of the YSI 6136 Turbidity Sensor was verified through the US EPA's Environmental Technology Verification Program (ETV).

To order, or for more info, contact
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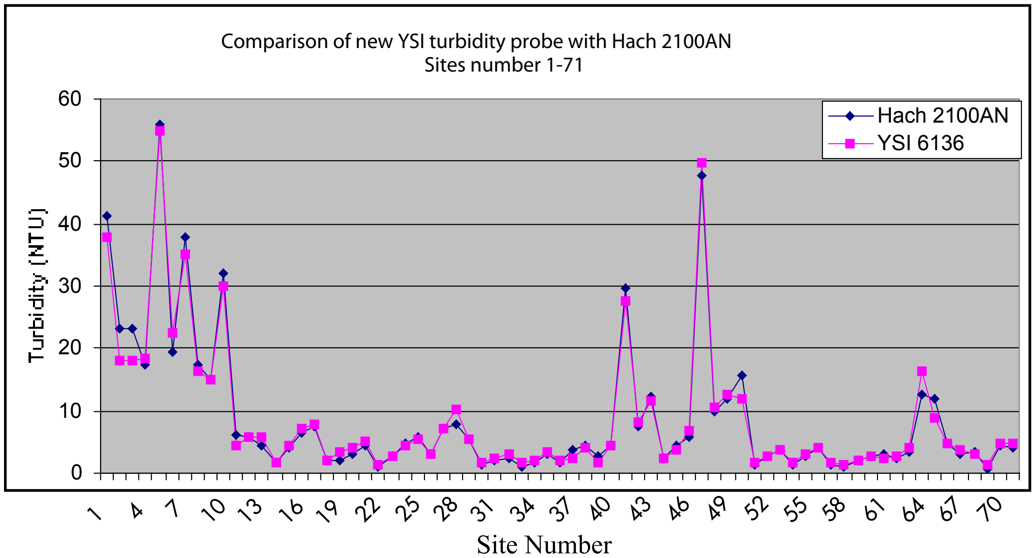
*Sensors with listed with the ETV logo were submitted to the ETV program on the YSI 6600EDS. Information on the performance characteristics of YSI water quality sensors can be found at www.epa.gov/etv, or call YSI for the ETV verification report. Use of the ETV name or logo does not imply approval or certification of this product nor does it make any explicit or implied warranties or guarantees as to product performance.

YSI incorporated
Who's Minding the Planet?®

Excellent agreement with the industry standard

Extensive empirical field and laboratory tests performed by YSI and independent agencies in Alpha and Beta studies document close agreement between *in situ* measurements made with the YSI 6136 turbidity sensor and data from the Hach® 2100AN, a laboratory instrument recognized as the standard for turbidity measurement.



Comparison of turbidity measurements made with the YSI 6136 Turbidity Sensor and Hach® 2100AN at 70 different riverine and lacustrine sites exhibiting widely varying (lower) turbidity ranges.

YSI 6136 Sensor Specifications

	Range	Resolution	Accuracy
Turbidity• 6136 Sensor* ETV	0 to 1,000 NTU	0.1 NTU	±2% of reading or 0.3 NTU, whichever is greater**

• Maximum depth rating for all standard optical sensors is 200 feet, 61 m. Turbidity is also available in a Deep Depth option (0 to 200 m).

**In YSI AMCO-AEPA Polymer Standards.

Applications include:

- Dredging
- Storm water
- Construction site monitoring
- Vertical profiling
- Long-term studies
- Surface water evaluations
- Circulation in lakes, reservoirs, bays, and estuaries

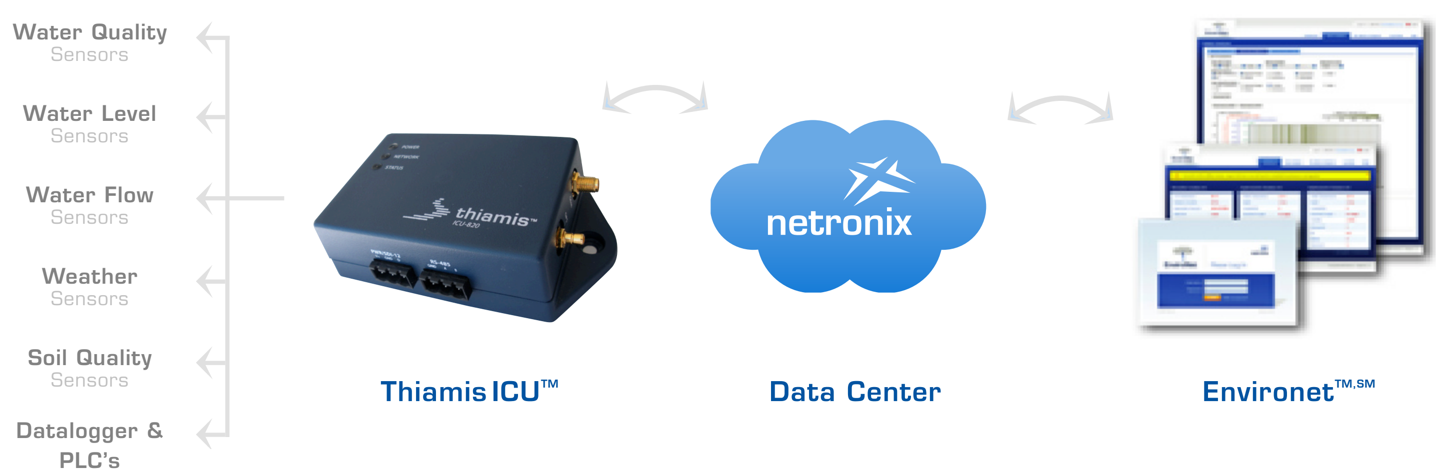
thiamis™

ICU 820

- 4-in-1 Controller, Data logger, Modem and GPS
- Communications Link Fail Over
- Over-the-Air Configuration
- Plug-and-Play
- Low-Power

The Thiamis™ ICU (Intelligent Control Unit) is a vital component of Netronix's remote monitoring suite. It combines control, data logging, global positioning and telemetry into one compact and purpose-built device, making it the most advanced and cost effective solution for remote monitoring applications in the environmental sector.

The Thiamis™ ICU 820 can interface with–and control–any type of sensor or external device in the field and establishes direct, secure communications with Netronix's data center, via its built-in GSM modem. The Thiamis also allows for alternate means of telecommunications, both for fail-over and to accommodate deployments in remote regions where GSM may not be available. The Thiamis is designed for plug-and-play operation, with no complex installation, and supports over-the-air configuration and re-programming, reducing or eliminating costly field trips.



product specifications

communications

Quad-band EGSM	850/900/1800/1900 MHz
Output Power	Class 4 (2W) @ 850/900 MHz
	Class 1 (1W) @ 1800/1900 MHz
Sensitivity	-107 dBm (typ.] @ 850/900 MHz
	-106 dBm (typ.] @ 1800/1900 MHz
GPRS	Class 10
Antenna	SMA male connector
SIM Card	Pre-installed

gps

Sensitivity	-159 dBm (indoor operation)
Accuracy	<2.5 m (8 ft)
Channel	20
SBAS Support	WAAS and EGNOS
Correlators	> 200,000
Antenna	SMB jack connector

controller / data logger

Clock	Real-time
Memory	4MB (up to 16MB)
Digital Ports	RS-485, RS-232 (3 Multiplexed), SDI-12
DeltaPort	Expansion port for Analog and Digital I/O modules

general

Input Voltage	6-24VDC
Current Consumption	50mA
Temperature Range	-30 °C to 75 °C (-22 °F to 167 °F)
Humidity Range	0-85% non-condensing
L x W x H	5.1”(130mm) x 2.72”(69mm) x 1” (30mm)

certifications

CE, FCC, PTCRB, RoHS	*more certifications in process

Note: Every Thiamis™ ICU it's supplied with GSM/GPS antenna and mounting base.

netronix™
where technology meets innovation

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